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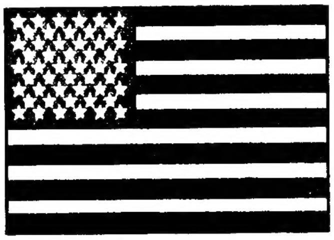

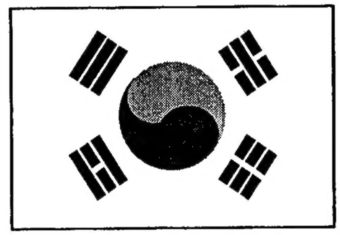

Contract Report SL-95-2
UAST-CR-94-003

JOINT U.S./ROK R&D PROGRAM FOR NEW UNDERGROUND AMMUNITION STORAGE TECHNOLOGIES

FINAL REPORT

UNDERGROUND AMMUNITION STORAGE FACILITIES ANALYSIS

by

Robert R. Arnold
Michael J. Moran
Keith Dobson
Les Kahalekai

MTA, Inc.
2225 Drake Avenue SW, Suite 8
Huntsville, Alabama 35805

April 1995

Prepared for U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, Mississippi 39180-6199

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US Army Corps
of Engineers
Waterways Experiment
Station

Joint U.S./ROK R&D Program for New Underground Ammunition Storage Technologies

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WES

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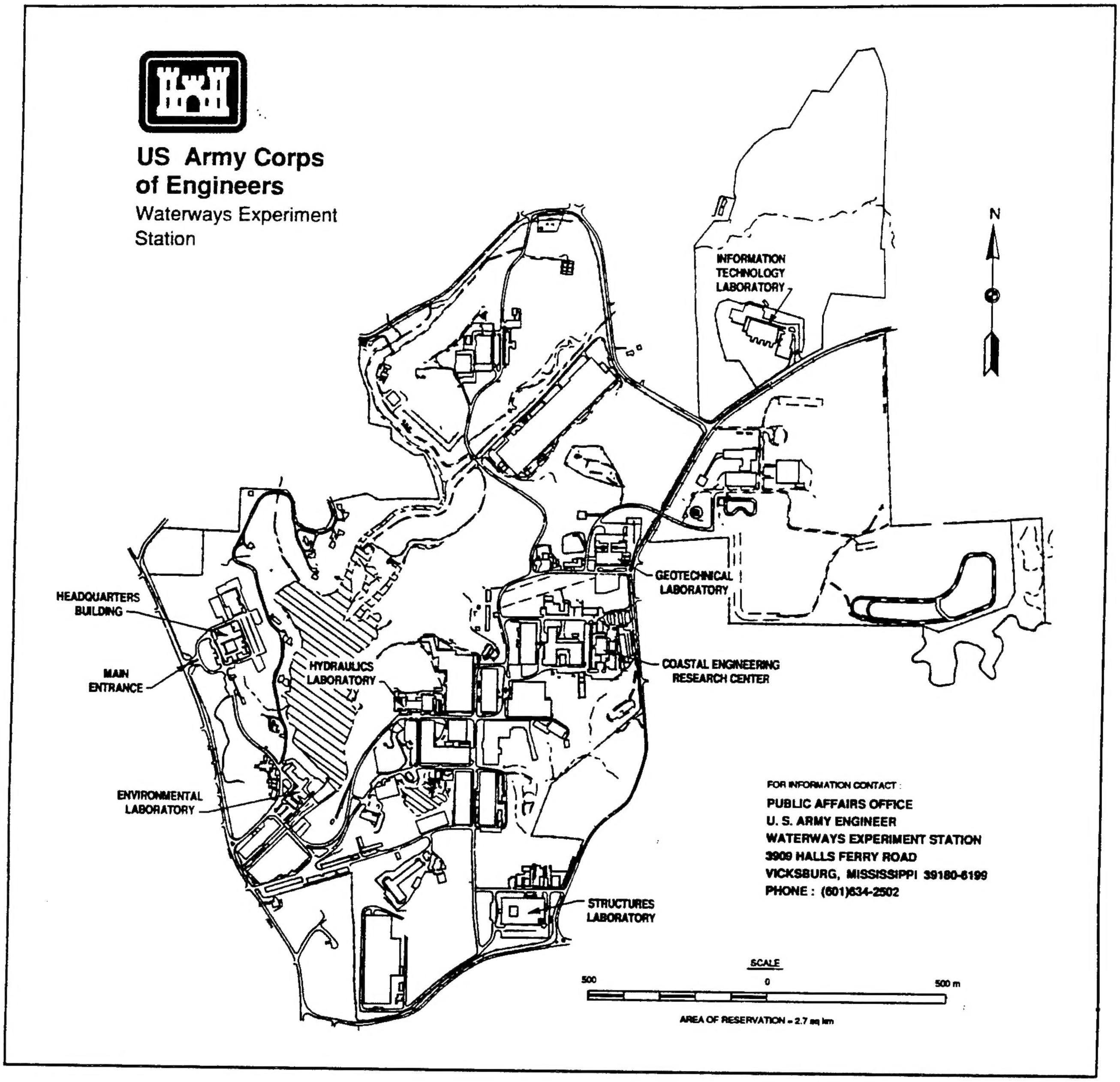

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PREFACE

In September 1993, the Huntsville, AL, office of MTA, Inc., under contract to the U.S. Army Engineer Waterways Experiment Station (WES), undertook an analysis of the economic and qualitative factors which would influence considerations to replace existing aboveground ammunition storage with underground storage facilities at eight U.S. Army installations in the United States. The work was done under Contract No. DACA39-93-C-0128, with the period of performance 2 September 1993 through 2 March 1994.

This task was performed as a component of the Joint U.S./Republic of Korea (ROK) R&D Study for New Underground Ammunition Storage Technologies. Mr. Gary Abrisz, U.S. Army Technical Center for Explosives Safety, was the U.S. Program Manager for the joint study. Mr. L. K. Davis, Geomechanics and Explosion Effects Division (GEED), WES, was the U.S. Technical Manager. During the period that this task was performed, COL Kim Myung Ki, ROK Ministry of Defense, was the ROK Program Manager. Dr. Song So-Young, ROK Agency for Defense Development, was the ROK Technical Manager.

The MTA study was monitored by Mr. Charles E. Joachim, GEED, Structures Laboratory (SL), WES. Chief of GEED was Dr. Jimmy P. Balsara. Mr. Bryant Mather was Director, SL.

The ammunition storage facilities analysis documented in this report was prepared by Messrs. Robert R. Arnold, Michael J. Moran, Keith Dobson, and Les Kahalekai, MTA.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acre	4046.9	square meter
cubic foot	0.02832	cubic meter
cubic yard	0.7646	cubic meter
foot	0.3048	meter
pound	0.4536	kilogram
short ton	907.2	kilogram
square foot	0.09290	square meter
square mile	2.590×10^6	square meter

EXECUTIVE SUMMARY

This study examines the economics and qualitative decision factors which would support a decision to replace existing aboveground ammunition storage facilities with underground ammunition storage facilities at eight U.S. Army installations in the United States. The MTA Team of researchers visited the installations and noted the condition and operational status of the ammunition facilities. The Team evaluated shortfalls in storage capacity, safety, security, or other management functions at the existing storage site through frank discussions with ammunition managers, Quality Assurance Specialists Ammunition Surveillance (QASAS), and representatives of the Director of Logistics and the Director of Public Works.

The Team then synthesized the information gathered by considering four alternatives to meet any future expansion needs in ammunition storage. These alternatives were:

I) Expand at existing aboveground storage area with aboveground magazines;

II) Retain existing aboveground structures and build underground facilities to meet expansion needs;

III) Abandon the existing aboveground storage structures and relocate all facilities underground; and

IV) Abandon the existing aboveground structures and build a new aboveground storage facility.

The MTA Team identified Alternative IV after visiting Fort McCoy, Wisconsin, and Fort Dix, New Jersey, as a necessary option in this study to reflect reality at a number of the sites.

The Team used a life cycle cost model based on the present value (PV) of all design, construction, and annual recurring operating expenses of each applicable alternative for each installation. As an adjunct life cycle tool, the equivalent annual cost (EAC) of these dollar outlays over time was computed. These economic models were applied at two interest rates to show both present macroeconomic conditions (5 percent) and a projected inflationary scenario

(10 percent). The life cycle cost model assumed a 30-year useful life of the ammunition storage area. The PV and the EAC analyses are presented at the conclusion of each installation portion of the study.

After in-depth interviews with installation ammunition and logistics managers, the MTA Team determined some common threads of concern, such as operational safety, security, and environmental factors, which the life cycle cost and other economic models ignored. In an effort to account for these nonquantifiable concerns, the Team used the Analytic Hierarchy Process (AHP) to complement the more traditional life cycle cost model which considers only economic factors. The AHP gives the decision maker a weighted order of preference for the alternatives under study. The advantage of the AHP is that this model can incorporate economic factors, such as the present value of the cash flows and the amount of real estate each alternative requires with important quantitative factors.

MTA prepared a questionnaire to which the installation subject matter experts (QASAS and ammunition managers) responded to indicate a preference ranking for the first tier characteristics of operations, economy, and environment. Then the MTA Team rank ordered a second tier of characteristics under each of the first tiers. For example, the experts indicated a number of characteristics or qualities under operations. Some of the second tier characteristics of operations were safety, security, haul distance to ranges, and suitability of terrain. Some of the second tier characteristics of the environmental considerations were the impact on ecosystems and aesthetics. The second tier characteristics of the economic consideration were the present value of the alternatives and the real estate impact. The latter are obviously quantitative characteristics which do not rely on anyone's opinion, but reflect actual numerical data. Thus, the AHP can combine qualitative and quantitative data to produce a weighted preference ranking of the possible alternatives. The AHP along with the life cycle model gives a more complete guide to the decision maker for selecting the appropriate alternative for future ammunition storage.

The study also considers the real estate which each alternate demands. This real estate consideration became paramount at installations with limited choices for the ammunition storage locations. The Quantity-Distance (QD) safety area associated with each alternative determines the real estate acreage impact at the installation. The study shows that a prime advantage of

underground ammunition storage is the significantly less QD area compared to the aboveground storage areas. Current research in underground storage design may reduce the required QD even further.

The study presents two quantitative decision criteria: life cycle costing and real estate encumbrance; and one combined qualitative/quantitative criteria: the AHP to assist in the selection of a particular alternative. MTA believes that a combination of the traditional engineering economy methods (which emphasize the time value of money and real estate impacts) along with the AHP (which is an excellent method to weigh those nonquantifiable factors of safety, security, environmental concerns) is the preferred method to make ammunition storage expansion decisions.

CHAPTER 1
INTRODUCTION

1.0 Introduction

The scope of this study is to provide a Life Cycle Cost (LCC) Analysis of three options for storing ammunition at a selected sample of U.S. Army installations in the continental United States. In many complex decisions, there are qualitative issues to consider along with the quantitative factors such as life cycle costs. This study presents a method which considers multiple qualitative decision factors, such as, safety and security in addition to the traditional economic factors. The use of the Analytic Hierarchy Process (AHP) allows the decision maker to systematically compare two qualitative or quantitative factors at a time to build a preference hierarchy which can be very useful in deciding ammunition storage modes.

1.1 Ammunition Storage Options

The options for expansion or replacement of existing ammunition and explosive storage facilities considered in this study are:

* Maintain aboveground storage structures and expand aboveground for future storage requirements;

* Retain aboveground storage structures and build underground for future storage requirements; and

* Abandon/demolish aboveground storage facilities and build underground.

1.2 Major Considerations

The following are the major considerations in investigating the feasibility and advisability of underground ammunition storage:

* A need for new ammunition storage facilities - A U.S. Army installation may or may not require new or additional ammunition storage facilities. The excellent ammunition storage facilities at Fort Campbell and Fort Knox, for example, serve the Army's present and foreseeable needs.

* Design Costs - Underground ammunition storage requires a rigorous geological engineering analysis, in addition to the typical aboveground storage facility planning considerations. Design costs for underground construction are based on the nature of the rock formation at the site and the tunnelling technique employed. Whenever possible, the use of a Tunnel Boring Machine (TBM) is preferable to the more dangerous and costly Drill and Blast technique. This study uses the drill and blast method costs to evaluate life cycle present value (PV) and equivalent annual costs (EAC).

* Cost of Construction - Aboveground construction costs are normally always less than underground construction costs. The standard Stradley earth-covered ammunition storage bunker design is adaptable to most aboveground storage sites. On the other hand, there is no standard underground storage facility design at present. Each underground storage facility must be designed for the on-site geological conditions as well as the storage mission. Research in tunnel and chamber design promises further reduction in the real estate required for the exclusion safety area around an underground ammunition storage facility.

* Real Estate Cost and Availability for Expansion - The amount of usable ground at a given site is a primary consideration in determining the optimum storage option. If an installation has ample real estate and has no quantity-distance (Q-D) problems due to encroaching civilian or military populations, the more costly underground storage must be justified on policy, operational, environmental, safety and security grounds. If, on the other hand, the installation has limited land, the significant savings in Quantity-Distance (Q-D) area with underground storage becomes significant. This study presents net real estate impacts of the alternatives. In every instance the underground storage option uses the least real estate and offers the Army the option of using the land occupied by the existing Ammunition Supply Points (ASP's) for other more productive purposes.

* Safety and Security - Underground storage facilities are safer for a number of reasons. The Department of Defense ammunition storage standard (DOD 6055.9 STD October 1992) for the proper storage of munitions underground allows a significant reduction in Q-D safety distances. An underground storage facility designed to have two tunnel portals servicing a number of storage chambers can offer a significant reduction in the security costs.

* Unique Equipment - Underground storage facilities use clean-burning material handling vehicles. This cost advantage for aboveground storage may diminish as the requirement for clean-burning vehicles increases in all storage environments. For the purposes of this study, there is no distinction between the equipment required to operate an aboveground and an underground ammunition storage facility.

* Labor - This study purposefully does not recognize the potential labor savings associated with underground storage. The labor savings associated with grounds maintenance is significant as is the reduced security work force. However, the work force at every installation was at such a reduced level that it is unlikely additional reductions in labor are possible even if the installation builds underground facilities. Therefore, the labor input to the life cycle cost models in this study reflect equal labor costs for all alternatives at a given installation.

* Geology and Topography - Underground storage is feasible only in areas having significant high ground or relief which would permit tunnelling horizontally into the hillsides. Tunnels which have downward sloping entrances are not desirable. Other major considerations for underground storage are ground water levels, rock competency, homogeneity of rock (i.e., number of fractures), and dangerous gases.

* Underground Ammunition Storage (Alternative III) assumes multiple storage chambers. One important design parameter is the chamber separation distance to prevent explosion propagation by rock spall. To prevent propagation DOD Ammunition and Explosives Safety and Standards, DOD 6055.9-STD October 1992 require minimum chamber separation distances which are a function of the net explosive weights (NEW) in adjacent chambers. Since underground storage chambers in this study will have floor areas of 2500 to 4000 square feet, the net explosive weight planned for each chamber will be at least 500,000 pounds. The NEW

the net explosive weight planned for each chamber will be at least 500,000 pounds.[1] The NEW of the adjacent chambers must be added together to determine the chamber separation. These minimum chamber separation distances are not dependent on the type or condition of the rock. The table below extracted from Table 9-20, DOD 6055.9 STD shows chamber separation distances to prevent explosion propagation for typical NEW per adjacent chamber:

NEW Per Chamber	Min Separation Distance (Propagation)
100,000 pounds	88 feet
250,000	120
500,000	150

MTA has used the 500,000 pounds NEW per chamber to determine the minimum chamber distance for this study. The actual Maximum Credible Event (MCE) may in fact be considerably less, perhaps in the 25,000 to 100,000 pound NEW range but the authors elected to detail a conservative chamber separation distance of 150 feet for a 500,000 pound loading for this study.

* Another consideration in underground ammunition storage is to provide sufficient chamber separation to prevent any physical damage (not explosive propagation) to stored ammunition in an adjacent chamber by rock spall. A designer would use this larger chamber separation distance when the ammunition/explosives are of such value or importance that no damage from rock spall is acceptable. Alternatively, the designer could provide reinforced concrete lining panels to contain the rock spall. These separation distances are a function of the net explosive weight and the rock type. Soft sandstone formations require less separation distance than granite formations. The table below also extracted from Table 9-20 in DOD 6055.9 STD October 1992 shows the larger separation distances involved in preventing damage by rock spall:

NEW	Rock Type	Min. Separation (damage)
100,000 pounds	Soft	160 feet
100,000	Medium	200
100,000	Hard	230

[1]A table of factors for converting non-SI units of measurement to SI units can be found on page viii.

NEW	Rock Type	Min. Separation (damage)
250,000	Soft	220
250,000	Medium	270
250,000	Hard	310
500,000	Soft	280
500,000	Medium	340
500,000	Hard	400

* Since the probability of an event is so small, there is reasonable basis to design an underground storage facility with chamber separation distances sufficient only to prevent explosion propagation to an adjacent chamber. There is a considerable cost to provide the larger chamber separation to prevent physical damage by rock spall. For example, chambers in hard rock with 500,000 pounds NEW require 400 foot separation to preclude physical damage from rock spall. This compares to 150 foot separation to preclude explosion propagation.

* Rock overburden on underground storage chambers should be thick enough to prevent debris throw. The thickness of required overburden (C_c) is a function only of the net explosive weight (W in the following equation) and not a function of the rock type. Overburdens of sandstone and granite provide the same protection against debris throw for a given net explosive weight. The formula $C_c=2.5W^{1/3}$ gives the required overburden to prevent debris throw from an explosion in underground storage chambers. For a NEW of 500,000 pounds the required overburden is approximately 200 feet. MTA investigators used the 200 foot overburden criteria to select potential sites for underground storage in Alternatives II and III in this study.

* Rock overburden sufficient to prevent airblast effect is much less than the overburden to preclude debris throw. Airblast effects through the overburden become negligible when the depth exceeds $0.75W^{1/3}$. Thus the 200 foot criteria for debris throw far exceeds the 60 foot overburden depth criteria for airblast effects through the overburden. ($0.75(500{,}000)^{1/3}$ = 60 feet).

* This study compares the real estate requirements of the alternatives against the existing aboveground ASP areas. The study applies the airblast and debris throw criteria of DOD 6055.9-STD to determine the Q-D areas specified for the effects of an explosion from the tunnel entrances. Since the tunnel system considered in this study has two entrances, the Q-D area is increased by the reinforcing effect of blast waves emerging from both entrances. This event could occur if the explosion were to take place in one of the deepest chambers. An event in a chamber close to one of the entrances would probably not produce the reinforcing effect on the overpressures.

1.3 Methodology

* MTA personnel visited the following U.S. Army installations during the period October - December 1993:

Fort McCoy, WI	Fort Drum, NY	Fort Dix, NJ
Fort Knox, KY	Fort Campbell, KY	Fort Huachuca, AZ
Fort Carson, CO	Yakima Training Center, WA	

MTA personnel visited the key ammunition managers at each installation to determine the adequacy of the existing ammunition storage and handling facilities. MTA personnel asked the ammunition managers at each installation to candidly assess the situation and assess if the existing facilities met the mission requirements. If the facilities were not sufficient for the installation's needs, MTA personnel determined what additional facility storage space would fit the present and projected needs of each installation. The turbulence of the realigning and downsizing of the U.S. Army presented challenges to anticipating future ammunition storage requirements.

* MTA assessed the situation at every installation and determined the size of the ideal ammunition storage expansion, if appropriate. MTA then created a conceptual cost estimate for the design and construction of the feasible alternatives based on historical cost studies.. In some cases, MTA identified a fourth alternative which was to build a new aboveground ASP and abandon the existing ASP.

* MTA recognized that the decision to replace existing ammunition facilities is complex. Many factors other than monetary costs are involved. These factors do not lend themselves easily to quantification in the traditional economic models. Factors such as safety, security, ecological impact, etc. are examples of these qualitative factors. MTA considered these qualitative factors significant enough to present a method to consider them. MTA has prepared an analysis of each alternative based on pair-wise comparisons of qualitative factors mentioned previously coupled with some very quantifiable factors such as life cycle present value and Q-D areas. MTA used input from the subject matter experts at each installation to create an analytic hierarchy model to evaluate alternatives.

1.4 Life Cycle Calculations

The life cycle present value costs (PV) and equivalent annual costs (EAC) of each alternative was computed for each installation. These calculations were performed using interest rates of 5% and 10% and a project life of 30 years.

The life cycle costs in this study consist of the design and construction costs plus the annual operating costs of labor, equipment and plant maintenance. Life cycle costs may also include the cost of salvage or restoration of the construction site to a green field condition. This study will not include the salvage or restoration costs. This is in keeping with the usual practice of using abandoned ammunition storage structures for other storage purposes.

The annual operating costs for these life cycle cost calculations assume no variation in the labor, equipment, or maintenance costs. There is difficulty in determining what labor savings were associated with the various alternatives because in every instance the labor force presently authorized to run the ammunition operations was at extremely low levels. It is unlikely that any actual labor savings could be realized by building underground facilities as mentioned previously.

This study does not recognize any variation in the annual equipment or maintenance costs. It was apparent during the site visits that the actual annual expenditures for replacement of equipment and plant maintenance at the installations do not reflect the dollars needed to properly

maintain the existing ASP's. Hence, any use of the data for equipment and maintenance to compare against projected underground storage annual costs would give inaccurate information.

This study does not consider utilities annual operating costs because every installation which MTA personnel visited failed to meter electrical power to the ASP. Thus, it was not practical to speculate what savings in utilities costs an underground ASP could realized compared to an equivalent aboveground ASP. The major utilities demand at aboveground storage sites is for perimeter lighting. It is obvious that the shorter perimeter lighting associated with a typical underground facility will use proportionally less electrical power. However, many underground ammunition storage facilities have high humidity conditions which require mechanical dehumidifying equipment. One can speculate that the cost savings in perimeter security lighting costs would be offset by power costs for dehumidifying the underground storage chambers.

The mechanics of determining the life cycle PV and EAC consists of computing the design and construction costs for each alternative and determining the annual labor, equipment, and maintenance historical data. The PV is determined by multiplying the present worth factor by the stream of annual costs (labor, equipment, labor) to calculate a present dollar value of that stream of expenditures over the 30 year life of the typical ammunition storage project using an appropriate interest rate of 5% and 10%. The present values will provide a guide to the decision maker as to the feasibility of each alternative.

Similarly, the EAC is determined by computing the equivalent annual cost of the initial design and construction costs. This is done by multiplying the annual cost factor by the initial design and construction cost estimate to obtain an equivalent annual cost of the design and construction. This equivalent annual cost of construction is then added to the annual operating costs of labor, equipment, and maintenance to obtain the total equivalent annual costs.

1.5 Analytic Hierarchy Process (AHP)

1.5.1 Introduction

Decisions on allocating resources to accomplish projects are often biased when deliberations are limited to strictly financial impacts. The Department of Defense (DoD)

regulations for performing economic analysis focus on quantifiable benefits and costs. However, in many fields and processes qualitative non-economic factors can dominate. In the Ammunition Supply and Services field, explosive safety and security considerations permeate every facet of daily operations and procedures. Consequently, for this project a multi-criteria decision model was needed to combine quantitative and qualitative factors into the capital investment decisions. The model should not replace the decision maker but improve the decision making process by a systematic consideration of all relevant factors. One such model is Dr. Saaty's "Analytic Hierarchy Process" (AHP).

1.5.2 Description of AHP

The Analytic Hierarchy Process is a rational and systematic approach for finding a solution to a problem. The method allows decision makers to partition large unmanageable problems into smaller parts that are easier to handle. It provides decision makers with the ability to include qualitative and quantitative criteria to form a rating for each of the alternatives. These ratings may then be used as a basis for project selection.

Four steps are used to solve a problem with AHP:

(1) Build a decision "hierarchy" by decomposing the general problem into individual criteria.

(2) Gather relational data for the decision criteria and alternatives.

(3) Estimate the relative weights of the decision criteria and alternatives using the "proportional method" or the "*eigenvalue* method."

(4) Aggregate the weights of the criteria and alternatives into a priority vector of ratings for the alternatives.

In general, the AHP reflects the natural tendency of the mind to sort elements of a system into different levels and to group like elements in each level. It provides a scale for measuring intangibles and a method for establishing priorities. The AHP tracks the logical consistency of

judgments used in determining priorities. It leads to an overall estimate of the desirability of each alternative. The AHP takes into consideration the relative priorities of factors in a system and enables decision makers to select the best alternative based on their goals. It provides a single easily understood, flexible model that enables people to participate directly in the process and can generally understand how results are derived.

1.5.3 Application of the AHP to the Ammunition Storage Problem

MTA's Project Plan provided an approach to determining an optimum ammunition storage site for a specific installation. Based on initial site surveys, it was very apparent that non-quantifiable factors dominated the ammunition storage and supply operations of each installation. Therefore, MTA turned to the AHP as a process to help synthesize these data elements and to incorporate site expert judgments into the recommendations more directly. The first step was to develop a hierarchy model of the problem. MTA built a decision "hierarchy" model whose final form is shown in the figure. The highest level is the focus, "Best Storage Alternative", at the next level are the Major Categories of factors that define the focus, the third level down contains the criteria in clusters that are used to evaluate the alternatives. The bottom level shows the alternatives for ammunition storage which were defined earlier.

1.5.4 Definition of Terms for the Ammunition Storage Problem Model:

Operational: Major category of non-quantifiable factors involved or are impacted by the day to day activities of operating an ASP in support of training.

Economical: Major category of quantifiable factors for constructing and sustaining an ASP operations.

Environmental: Major category of non-quantifiable factors impacting the quality of life of the installation, its surrounding fauna and flora that result from operating an ammunition storage site.

Safety:	A characteristic of a storage site that describes the degree its physical features and storage facility layout contribute to reducing the probability of catastrophic damage to property, stocks and personnel.
Maneuver Space:	A characteristic of a storage site that describes the lack of limitations or restrictions the site imposes on maneuvering units and weapon systems.
Security:	A characteristic of a storage site that describes the degree its physical features and storage facility layout aid the safeguarding of all ammunition stocks.
Accessibility:	A characteristic of a storage site that defines the ease of access to the site from major road networks for commercial trucks delivering or picking up ammunition cargo.
Haul Distance:	A characteristic of a storage site that describes the average over-the-road distance to training sites where the ammunition is consumed.
Life Cycle Costs:	A quantifiable factor equal to the total Labor, Equipment, Maintenance and Construction Costs for a storage site.
Encumbrance:	A quantifiable factor equal to the total real estate acreage that is contained within the Quantity Distance (QD) limits of a storage site.
Aesthetics:	A characteristic of a storage site that describes its beauty and appeal to the senses of observers.
Ecological Impact:	A characteristic of a storage site that describes its positive effect on the surrounding terrain, its fauna and flora.
Terrain Suitability:	A characteristic of a storage site that describes the degree that the site's physical features aid in constructing and underground or an aboveground ammunition storage site.

Encroachment: A characteristic of a storage site that describes its vulnerability to the (present and future) spread of human habitation within its QD limits.

1.5.5 Generation of Relational Data

To compute the ratings of the alternatives, MTA needed to obtain relational data on the criteria as well as on the alternatives. Performing Step 2 of the AHP process generates relational data for the decision criteria and the alternatives through the use of judgement matrices for qualitative data and the proportional method for quantifiable data. MTA enlisted the aid of site experts to obtain some of this information. A questionnaire was developed to obtain judgments from the ammunition storage and supply experts at the various installations on the relative importance of the models criteria in the "hierarchy." A sample of this questionnaire is at Appendix C. In this manner, MTA incorporated site specific intangible factors into the decision process. Each of the installation inputs (except Fort Campbell) are summarized in Tables 1 through 4 in Appendix C. An example of this tabulation for Fort Drum is shown below.

Relative Weights of the Operational Criteria for Fort Drum

	1	2	3	4	5	Priority
1. Safety	1	3	3	5	7	0.458
2. Maneuver Space		1	1/2	1	1	0.101
3. Security			1	5	7	0.294
4. Accessibility				1	3	0.093
5. Haul Distance					1	0.054
Inconsistency Ratio:	0.096					

Figure 1. Fort Drum Tabulation

The numbers below the diagonal in the transpose positions are the reciprocals of those shown. The values in the interior columns (matrix elements) of the table were determined by applying Saaty's 1-9 Judgment Scale to the site expert's input. For information purposes this scale is shown below.

Intensity of Importance	Definition	Explanation
1	Equal	Elements contribute equally
3	Moderate	Experience slightly favors one element
5	Strong	Experience strongly favors one element
7	Very Strong	Demonstrated practice favors one element
9	Absolute	Evidence beyond a doubt favors one element
2, 4, 6, 8	Intermediate Values	Compromise option

The choice of the 1-9 scale is based on the psychological limit of humans being able to handle 7 ± 2 items in a simultaneous comparison. It also corresponds well to the ability to make qualitative distinctions by the use of the terms; Equal, Moderate, Strong, Very Strong and Absolute. Compromises between adjacent descriptors are allowed for increase precision which results in a 9 level scale.

The matrix elements of Figure 1 are the ratios developed from applying a pairwise comparison technique to the Operational Criteria listed vertically by number. These ratios are obtained from answers to questions such as:

> "Safety is how much more important or influential as an Operational Factor than Security in determining an optimum storage site for ammunition?"

The respondent answers by placing an "X" in the appropriate column for this pairwise comparison table in the questionnaire to indicate his or her judgement. The headings of the columns of the tables in the questionnaire correspond to the Definitions in the 1-9 Scale. In the example of Figure 1, Safety was judged to be "3 times" or "Moderately" more influential than Maneuver Space as an Operational Factor in determining the optimum ammunition storage. Safety was judged "7 times" or "Very Strongly" more influential than Haul Distance as an Operational Factor in determining the optimum ammunition storage. If cardinal transitivity is maintained then Haul Distance would be judged "3/7 times" as influential as Maneuver Space.

At Fort Drum haul distance and maneuver are judged to be equally influential. This inconsistency is natural in human judgements and is an integral part of the AHP. The degree of judgement inconsistency is measured by the use of the Inconsistency Ratio. Dr. Saaty recommends relooking judgements if this ratio is greater than 0.10. However, the judgements should not be changed just to improve consistency.

In this fashion, a weight for each Operational Criterion may be determined. Similar matrices were developed for the Economical and Environmental Criteria through the pairwise comparison technique. These are at Appendix C for each installation except Fort Campbell, since it already has underground storage.

The "Priorities" column in Figure 1 lists the weights for Operational Criteria as derived from the pairwise comparisons or judgment matrix obtained from the ammunition experts on site. Dr. Saaty proved that the eigenvector of the largest eigenvalue of the Judgement matrix accurately provides these weights. It is important to note that each installation site expert provided this information, therefore; the weights of the these criteria would reflect an installation site expert's bias, consequently the decisions for the installation's storage type will be biased also.

1.5.6 Synthesis of Relational Data

This section discusses the synthesis of all the information generated by the judgmental matrices of pairwise comparisons and the proportional method. The final result of the AHP as shown earlier is a rating of each alternative for each installation. These ratings are displayed in Tables 5 through 7 of Appendix C. The synthesis occurs through the use of matrix multiplication. The individual ratings are combined into a 2x5 matrices as shown below in the example of Table 8 for Fort Carson. As shown the alternatives are arrayed vertically while the criteria are arranged horizontally. The matrix elements are the ratings of each alternative against each criteria. This matrix is multiplied by the 5x1 matrix of Criteria weights to generate a rating (Priority Vector) of each alternative within a Major Category. The Major Category ratings are arrayed in a 2x3 matrix and multiplied by the 3x1 matrix of Major Category weights to yield an overall rating for achieving the goal of the problem, i.e., Optimum or Best Ammunition Storage for an installation. The final rating is shown as the Overall Vector of

Priorities in Table 8 (reproduced from Annex C). The alternative with the greatest rating is the most preferred option for that installation.

TABLE 8. Synthesis for Fort Carson

Weighted Ratings for Operational Factors

	5A	5B	5C	5D	5E				
I	0.068	0.138	0.207	0.452	0.140		0.284		OP Priority Vector
III	0.162	0.064	0.058	0.072	0.528	x	0.108		
III	0.77	0.798	0.735	0.476	0.333		0.461	=	(I-0.177, II-0.118, III-0.705)
							0.087		
							0.060		

Weighted Ratings for Economical Factors

	6A	6B				
						EC Priority Vector
I	0.471	0.094		0.875		
II	0.402	0.082	x	0.125	=	(I-0.393, II-0.374, III-0.233)
III	0.127	0.824				

Weighted Ratings for Environmental Factors

	7A	7B	7C	7D			
							EV Priority Vector
I	0.138	0.138	0.659	0.195		0.037	
II	0.064	0.064	0.156	0.088	x	0.239 =	(I-0.369, II-0.109, III-0.522)
III		0.798	0.798	0.185	0.717		0.409
							0.315

Overall Ratings of Alternatives

	OP	EC	EV				
							Overall Priority Vector
I	0.196	0.393	0.369		0.715		
II	0.141	0.374	0.109	x	0.067	=	(I-0.247, II-0.150, III-0.603)
III	0.663	0.233	0.522		0.218		

CHAPTER 2
FORT McCOY, WISCONSIN

2.0 Background

Fort McCoy is located between Sparta and Tomah on State Highway 21, 35 miles east of LaCrosse and 105 miles northwest of Madison. Fort McCoy supports the Army Reserve Readiness Training Center, the Consolidated Regional Training Activity, the 88th Explosive Ordnance Detachment, the 86th Army Reserve Command Equipment Concentration Site, and the Wisconsin National Guard Mobilization and Training Equipment. Over 300 active-duty soldiers serve at Fort McCoy, while more than 100,000 Guard and Reserve members train there annually.

MTA personnel visited Fort McCoy on 5-7 October 1993. On 6 October Mr. Jerry Hale, ASP Chief, met with MTA personnel to discuss the current and future ammunition operations/needs of Fort McCoy. Mr. Richard H. Cashin, USATCES, Savanna, IL, was also present.

2.1 Facts

MTA, Inc. personnel visited Fort McCoy on 5-7 October 1993 obtained the following information:

Present ammunition throughput is 2200 short tons per year. This quantity is concentrated in the late spring and summer periods. There is relatively little demand during the cold months of the year. Ft. McCoy maintains a 90 day supply during the most active months.

The ammunition haul road crosses an active state highway because most of the firing ranges are on the north side of the road. This means all ammunition haul vehicles must meet over the road transportation requirements which puts an unnecessary burden on the units which train at Fort McCoy.

The importance of Fort McCoy to the Army mission is reflected in the 102,000 soldiers who trained there in FY93. The ammunition manager expects to maintain the level of over 100,000 soldiers through 1998.

Ft. McCoy has recognized the shortfall in meeting the Army's training needs and maintaining the safety of the community. There are only 16,000 square feet of covered ammunition storage. Fort McCoy has programmed a Military Construction Army project to build an aboveground ammunition storage facility on the north side of the installation in FY98 for $6.5 million.

The Ammunition Supply Point manager, Mr. Jerry Hale, estimates that an ideal increase of 50% in covered storage area would meet the safety and maintenance needs in the mid- term. He based this estimate on the present shortfall in ammunition storage, handling, and surveillance space.

Fort McCoy has identified an Alternative IV which proposes to build an aboveground ammunition storage facility north of the state highway. This addition is part of the FY98 military construction request. Fort McCoy proposes to abandon the existing ASP and locate the new facility in the northeastern quadrant of the installation. The major access road to the proposed site would be State Highway 21.

Alternatives III and IV will solve some of the most pressing ammunition storage and operational problems. Any site north of the state highway will reduce the long haul distances to firing ranges, avoid crossing the heavily traveled state highway, and utilize the valuable real estate of the existing ASP more productively.

2.2 Alternative I

Alternative I will maintain the existing aboveground ASP facilities and expand the ASP with state of the art aboveground structures. This alternative would require the addition of three Stradley type earth-covered ammunition storage magazines at 2,000 square feet each. This expansion will require 0.60 acres of land to the west of the existing ASP for the actual site

construction and 184 additional acres for the Q-D safety area south of the state highway. (see Annex A).

2.2.1 Advantages

The lower cost of Alternative I is the prime advantage. The Federal Government already owns the land on which the expansion would take place. Standard Stradley earth-covered magazine design would be adapted to the site and reduce design costs. The planned maintenance and surveillance building would service the expanded storage facilities under Alternative I.

2.2.2 Disadvantages

Alternative I does not solve the problem of hauling ammunition across the major highway. Also, the large Q-D area will prevent expansion to the north, south, and east. Ammunition haul distances will remain a problem (i.e., up to 18 miles to some firing ranges). The long haul distances compound the hazardous driving conditions which exist at Fort McCoy in the winter. While making additions to the perimeter road net, security fencing, and the intrusion detection systems required for Alternative I, the integrity of the existing security system will temporarily be compromised.

2.3 Alternative II

Alternative II retains the existing aboveground storage structures and builds underground chambers to meet future storage needs. The 8,000 square foot increase in storage capacity will require the construction of two 4,000 square foot underground storage chambers, each accessed by their own adit. There are two sites that lend themselves to underground storage: grid 901797 and grid 825785. Both sites are hillsides which have sufficient rock overburden. Both adits would face the impact area.

2.3.1 Advantages

The primary advantage of Alternative II is that a significant portion of the ammunition storage capacity will be closer to the training areas. Construction of Alternative II will not interrupt the

security or the continuing operations of the current ASP. Furthermore, this alternative reduces the amount of ammunition hauled across state highway. Alternative II requires real estate (i.e., hillsides, bluffs, cliffs) which is of little use to the Army for training conducted at Fort McCoy. The new ammunition surveillance building proposed for the existing ASP would service the underground storage facility of Alternative II as well.

2.3.2 Disadvantages

Alternative II would require the simultaneous operation of two ASPs. Current manpower authorization may be inadequate to service such an operation efficiently. Security for the new storage facility would require additional intrusion detection systems and impose new demands on the security force. Finally, Alternative II has a higher initial cost than Alternative I.

2.4 Alternative III

Alternative III will abandon or demolish the aboveground storage facilities and build underground facilities. This alternative involves the most costly engineering, design, and construction costs but results in a ammunition storage facility which affords the most safety and security for Fort McCoy, and the surrounding community. This alternatives also allows for a complete reutilization of the real estate occupied by the existing ASP.

2.4.1 Advantages

Alternative III moves all of the ammunition closer to the training areas, and solves all of the problems associated with the hauling of ammunition across State Highway 21. Construction of Alternative III will not interrupt the security or the continuing operations of the current ASP. In addition, the real estate required for Alternative III (i.e., hillsides, bluffs, cliffs) would more than likely be of little use to the Army for training purposes at Fort McCoy. And as mentioned above, the real estate occupied by the current ASP could be used for other purposes in line with the industrial uses of adjacent areas. Finally, the new underground ASP will be easier to secure. The only areas that would have to be guarded are the doors to the two adits. The perimeter road and the perimeter fence would be significantly shorter.

2.4.2 Disadvantages

Alternative III is the most expensive alternative by far. The initial investment is significantly large and the long term operations and maintenance expenditures are uncertain. Underground storage of ammunition requires careful monitoring of moisture in the air as well as harmful gases such as methane and radon. A ventilation system with reliable monitoring devices is required for safe operation.

2.5 Alternative IV

Alternative IV will build a new aboveground ammunition storage facility in the northeast quadrant of Fort McCoy located away from the high use area of the present storage facility. This alternative recognizes the need for an entirely new ammunition storage facility at Fort McCoy, Wisconsin. This alternative will accommodate the 50% expansion of the existing storage space and will not have restrictive Q-D areas. This alternative will also feature delivery truck access located away from the populated areas of the installation.

2.5.1 Advantages

This alternative satisfies the expanded ammunition storage need and solves the Q-D problem at the existing ASP at moderate cost. Alternative IV solves the problems associated with the hauling of ammunition across the state highway. The new aboveground ammunition storage magazines will meet DOD standards and allow material handling equipment to be used. In addition, truck delivery to the new storage site will avoid the populated southern portion of Fort McCoy. The new location will increase the level of physical security because the storage facility will be located in a remote sector of Fort McCoy. This alternative ASP will be much closer to the training areas and firing points. This location will minimize unit transportation of ammunition and avoid the costly, time-consuming procedure of blocking and bracing ammunition hauled in unit vehicles. Also, construction of Alternative IV will not interrupt existing ASP operations.

2.5.2 Disadvantages

The remote location of the new ASP could be a challenge should an incident require a quick reaction time (i.e., fire, intrusion, injury, etc.). The new ASP might require more security because of the remote location. Alternative IV is most disruptive to the environment of all the alternatives considered.

2.6 Life Cycle Costs - Alternative I

Alternative I life cycle costs were computed as described in the introduction. First, the required expansion area of 8,000 square feet was satisfied by the addition of three Stradley Magazines in an area adjacent to the west boundary of the existing ASP. The estimated design and construction costs for this expansion of the ASP was $1.84 million. The annual operating costs of labor was calculated at $0.38 million per year for the five full-time, four temporary, and four part time employees at the ASP. Equipment costs were conservatively estimated at $44,000 per year to maintain and replace the pick-up trucks and fork lifts used in the ASP. The records for plant maintenance show an expenditure of only $3,800 for 1993 fiscal year. This low expenditure is suspect because of the obvious maintenance performed on the lightning protection system as well as the extensive grounds maintenance for earth berm repair, grass cutting, and snow removal. For this analysis, the maintenance costs were increased substantially to a level of $18,000 per year to reflect an adequate level of maintenance. Thus the total annual operating costs are the sum of labor, equipment and maintenance ($0.38 million + $0.044 million + $0.018 million = $0.442 million)

2.6.1 Present Value

The PV for Alternative I at 5% interest rate is therefore:

$1.84 million + PV of annual costs or

$1.84 million + (15.372 x sum of labor @$0.38 million + equipment @ $0.044 million + maintenance @ $0.018 million) = $8.63 million

The PV for this Alternative at 10% interest rate will yield:

$1.84 million + (9.427 x $0.442 million) or $6.01 million

2.6.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $1.84 million) + Annual Operating Costs or

(0.06505 x $1.84 million) + $0.442 = $0.562 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $1.84 million) + Annual Operating Costs or

(0.10608 x $1.84 million) + $0.442 million = $0.637 million per year

2.7 Life Cycle Cost - Alternative II

This alternative will build two underground storage chambers each accessed through an adit. They will provide 8,000 square feet of storage. The conceptual cost estimate based on a finished unit cost of $175 per cubic yard for the two storage chambers and $225 per cubic yard for the adit using the drill and blast method is $2.24 million. Applying the method outlined for Alternative I, the PV and EAC is similarly computed:

2.7.1 Present Value

The PV for Alternative II at 5% interest rate is therefore:

$2.24 million + PV of annual costs or

$2.24 million + (15.372 x sum of labor @$0.38 million + equipment @ $0.044 million + maintenance @ $0.018 million) = $9.03 million

The PV for this alternative at 10% interest rate will yield :

$2.24 million + (9.427 x $0.442 million) = $6.41 million

2.7.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $2.24 million) + Annual Operating Costs or
(0.06505 x $2.24 million) + $0.442 = $0.588 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $2.24 million) + Annual Operating Costs or
(0.10608 x $2.24 million) + $0.442 million = $0.680 million per year

2.8 Life Cycle Cost - Alternative III

This alternative will build an underground storage chambers system consisting of six 4,000 square foot chambers, accessed from one continuous adit in the shape of a horseshoe. There is a chamber which connects the two legs of the horseshoe for maintenance activities. The system will provide 24,000 square feet of storage. The conceptual cost estimate based on a finished unit cost of $175 per cubic yard for the two storage chambers and $225 per cubic yard for the entrance tunnel using the drill and blast method is $8.08 million. Applying the method outlined for Alternative I, the PV and EAC is similarly computed:

2.8.1 Present Value

The PV for Alternative III at 5% interest rate is therefore:

$8.08 million + PV of annual costs or
$8.08 million + (15.372 x sum of labor @$0.38 million + equipment @ $0.044 million + maintenance @ $0.018 million) = $14.87 million

The PV for this alternative at 10% interest rate will yield:

$8.08 million + (9.427 x $0.442 million) or $12.25 million

2.8.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of \$8.08 million) + Annual Operating Costs or

(0.06505 x \$8.08 million) + \$0.442 = \$.968 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of \$8.08 million) + Annual Operating Costs or

(0.10608 x \$8.08 million) + \$0.442 million = \$1.299 million per year

2.9 Life Cycle Cost - Alternative IV

This alternative will build a new aboveground ASP at a new site north of the state highway. A conceptual cost estimate was prepared to account for providing 24,000 square feet of storage at a cost of \$6.8 million. Applying the method outlined for Alternative I, the PV and EAC is similarly computed.

2.9.1 Present Value

The PV for Alternative IV at 5% interest rate is therefore:

\$6.8 million + PV of annual costs or

\$6.8 million + (15.372 x sum of labor @ \$0.38 million + equipment @ \$0.044 million + maintenance @ \$0.018 million) = \$13.59 million

The PV for this alternative at 10% interest rate will yield :

\$6.8 million + (9.427 x \$0.442 million) = \$10.97 million

2.9.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of \$6.8 million) + Annual Operating Costs or

(0.06505 x \$6.8 million) + \$0.442 = \$0.884 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of \$6.8 million) + Annual Operating Costs or

(0.10608 x \$6.8 million) + \$0.442 million = \$1.163 million per year

Table 1: Fort McCoy Life Cycle Cost Analysis (Millions of Dollars)

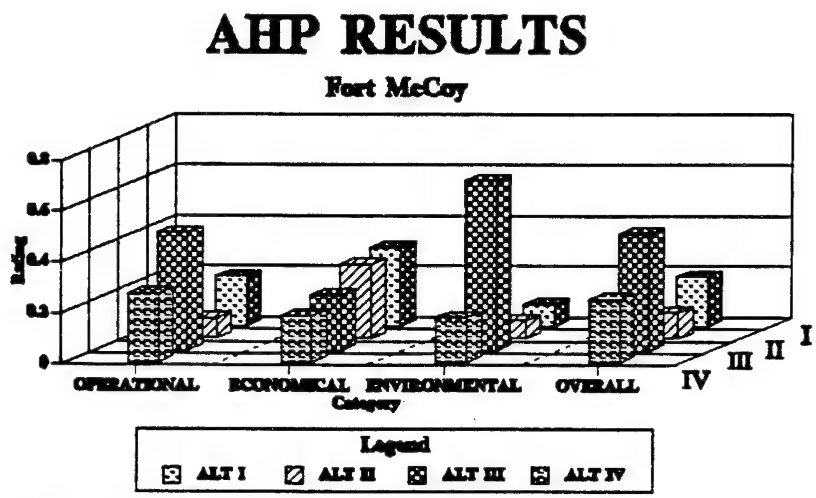
Method	Alt I	Alt II	Alt III	Alt IV
PV at 5%	8.63	9.03	14.87	13.59
PV at 10%	6.01	6.41	12.25	10.97
EAC at 5%	0.562	0.588	0.968	0.884
EAC at 10%	0.637	0.680	1.299	1.163

2.10 Analytic Hierarchy Process

Based on pair-wise comparisons of the multiple factors mentioned in the introduction, the AHP has a heavy preference for Alternative III with a relative weight of 0.457. This weight is almost double that of Alternative IV at 0.248. The AHP recommends total underground ammunition storage.

2.11 Recommendation

MTA recommends Alternative III as the best ammunition storage solution at Fort McCoy.



ALT I	0.195	0.309	0.087	0.195
ALT II	0.077	0.291	0.071	0.1
ALT III	0.461	0.217	0.669	0.457
ALT IV	0.267	0.183	0.174	0.248

Figure 2 Fort McCoy AHP Results

CHAPTER 3
FORT DRUM, NEW YORK

3.0 Background

Fort Drum is located nine miles east of Watertown, NY and is headquarters for the 10th Mountain Division and supporting units. The ASP supports the 10,000 soldiers of the 10th Mountain Division plus 40-50,000 Army Reserve Component Troops. The ASP also supports the New York Air National Guard.

MTA personnel visited Fort Drum on 2-3 November 1993. Mr. Howard Spelman, the assistant QASAS, escorted the MTA personnel. Mr. Karl Reiber, Chief of Ammunition Services, and Mr. Bill Bamann, Master Planner for the Directorate of Engineering and Housing, provided valuable information for this report.

3.1 Facts

Fort Drum's present ASP consists of thirty earth-covered magazines, one small arms ammunition warehouse, and five barricaded storage cells (protected by high berms on three sides). In addition, there is a field ASP adjacent to the main ASP which has seventeen barricaded storage pads and a new ammunition surveillance building. There is an ammunition residue return area located to the southwest of the ASP.

The condition of the magazines built from 1973 to 1988 is excellent. The three magazines built in 1940 are marginal. The small arms ammunition warehouse and the ammunition surveillance building were built in the 1989-90 time frame and are in excellent condition. The ammunition residue return area is marginally adequate.

Q-D areas limit any expansion of the current ASP to the north and to the west. The 1200 and 1800 foot Q-D extend beyond the southeast post boundary. However, Fort Drum can build additional magazines within the existing ASP without extending these Q-D limits.

The New York Air National Guard requires covered storage for the large ordnance it uses at Fort Drum. The Air Guard stores its bombs on three barricaded storage pads in the field ASP. This is clearly undesirable because of the environmental effects on the serviceability and handling of this large ordnance. Appropriate covered storage should be provided for the Air Guard.

Mr. Reiber and Mr. Spelman recommend 5,250 square feet of additional earth-covered storage to meet Fort Drum's future mission needs. This is an increase of 10% over the existing earth-covered storage available and excludes the storage requirements of the Air Guard mentioned above.

3.2 Alternative I

Alternative I will maintain the existing aboveground facilities and expand to met future needs with similar aboveground structures. This alternative would require the addition of three Stradley earth-covered ammunition storage magazines at 2,000 square feet each (see Annex A). In addition, the Air National Guard should fund construction of one Stradley ammunition storage magazine and two open sided roof structures to provide cover for the Air Guard's existing ammunition storage pads.

3.2.1 Advantages

Alternative I's primary advantage is its low acquisition cost: i.e., the Federal Government owns the land. The existing ammunition residue area, ammunition surveillance building, road network, and security fence are capable of servicing and supporting the additional storage facilities. Utilizing the standard Stradley earth-covered ammunition storage magazine reduces design costs.

3.2.2 Disadvantages

The disadvantage of Alternative I is the continuing problem of the Q-D area extending beyond the southeast post boundary. Also, Alternative I does not reduce the extensive grounds

maintenance costs associated with summer grass cutting, earth-cover maintenance, and winter snow removal.

3.3 Alternative II

Alternative II will retain the existing aboveground ammunition storage structures and build underground for future storage requirements. This alternative would require construction of storage facilities remote from the existing ASP. There are no ideal underground storage sites at Fort Drum; however, MTA personnel identified a potential underground storage site at grid 491785. Ward Hill at grid 505740 was considered a potential site but it is located across a public highway and is too close to the southeast installation boundary.

Alternative II consists of two large storage chambers each accessed by its own adits, respectively.

3.3.1 Advantages

Alternative II will bring a significant portion of the storage capability closer to the firing ranges. Also, the uniform temperatures of underground storage are in contrast to the harsh surface winter temperatures and will ease ammunition maintenance.

3.3.2 Disadvantages

Alternative II will create a security problem because of the need to monitor two storage sites. This alternative will stretch the limited manpower of the ammunition section to the limit because of the need to manage multiple sites. Also, the delivery and haul road network will require extensive upgrading in order to provide access for commercial trucks to the potential site for this underground construction. This alternative will require Q-D area in addition to the existing Q-D area. The problem of the existing Q-D area which extends beyond the post boundary will remain.

3.4 Alternative III

Alternative III will abandon or demolish the existing aboveground ammunition storage facilities and build new storage facilities underground. This alternative will use the same proposed site at grid 491785 as Alternative II. Alternative III consists of six large ammunition storage cells connecting the continuous, horseshoe shaped adit. There is also a small surveillance and maintenance chamber which connects the legs of the horseshoe shaped adit.

3.4.1 Advantages

Alternative III will require the least real estate of any alternative. This alternative will remove the existing problem of the Q-D area extending beyond the post boundary. An underground facility will minimize security requirements and will nearly eliminate grounds maintenance. Unlike Alternative II, Alternative III will make ammunition storage and maintenance much more efficient because of the constant year round temperatures inside the storage cells.

3.4.2 Disadvantages

Alternative III has the highest initial design and construction cost. The design must account for high water tables at Fort Drum. As in Alternative II, the existing access and ammunition haul road network must have extensive upgrades to accommodate commercial trucks.

3.5 Life Cycle Cost - Alternative I

3.5.1 Present Value

Alternative I consists of adding three Stradley magazines within the existing ASP at a total design and construction cost of $1.66 millon. The annual operating costs for labor, equipment and plant maintenance is projected at $0.70 million per year ($0.626 million labor + $0.044 equipment + $0.030 million plant maintenance).

The PV for Alternative I at 5% interest rate is therefore:

$1.66 million + PV of annual costs or

$1.66 million + (15.372 x $0.70 million) = $12.42 million

The PV for this alternative at 10% interest rate will yield:

$1.66 million + (9.427 x $0.70 million) = $8.26 million

3.5.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $1.66 million) + Annual Operating Costs or

(0.06505 x $1.66 million) + $0.70 million = $0.808 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $1.66 million) + Annual Operating Costs or

(0.10608 x $1.66 million) + $0.70 million = $0.876 million per year

3.6 Life Cycle Cost - Alternative II

This alternative will build two underground storage chambers each having there own adits. It will provide 6,400 square feet of storage. The conceptual cost estimate based on a finished unit cost of $175 per cubic yard for the two storage chambers and $225 per cubic yard for the adit using the drill and blast method is $1.99 million. Applying the method outlined for Alternative I, the PV and EAC are computed:

3.6.1 Present Value

The PV for Alternative II at 5% interest rate is therefore:

$1.99 million + PV of annual costs or

$1.99 million + (15.372 x $0.70 million) = $12.75 million

The PV for this alternative at 10% interest rate will yield:

$1.99 million + (9.427 x $0.70 million) = $8.59 million

3.6.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $1.99 million) + Annual Operating Costs or

(0.06505 x $1.99 million) + $0.70 million = $0.830 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $1.99 million) + Annual Operating Costs or

(0.10608 x $1.99 million) + $0.70 million = $0.911 million per year

3.7 Life Cycle Cost - Alternative III

This alternative will build an underground storage chambers system consisting of nine 6,600 square foot chambers connected by an horseshoe shaped adit. There is a tunnel which connects the two legs of the horseshoe shaped adit for maintenance activities. The system will provide 59,400 square feet of storage. The conceptual cost estimate based on a finished unit cost of $175 per cubic yard for the two storage chambers and $225 per cubic yard for the adit using the drill and blast method is $14.70 million. Applying the method outlined for Alternative I, the PV and EAC are computed:

3.7.1 Present Value

The PV for Alternative III at 5% interest rate is therefore:

$14.70 million + PV of annual costs or

$14.70 million + (15.372 x $0.70 million) = $25.46 million

The PV for this alternative at 10% interest rate will yield:

$14.70 million + (9.427 x $0.70 million) = $21.30 million

3.7.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $14.70 million) + Annual Operating Costs or

(0.06505 x $14.70 million) + $0.70 = $1.656 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $14.70 million) + Annual Operating Costs or

(0.10608 x $14.70 million) + $0.70 million = $2.259 million per year

Table 2: Fort Drum Life Cycle Cost Analysis (Millions of Dollars)

Method	Alt I	Alt II	Alt III	Alt IV
PV at 5%	12.42	12.75	25.46	N/A
PV at 10%	8.26	8.59	21.30	N/A
EAC at 5%	0.808	0.830	1.656	N/A
EAC at 10%	0.876	0.911	2.259	N/A

3.8 Analytic Hierarchy Process

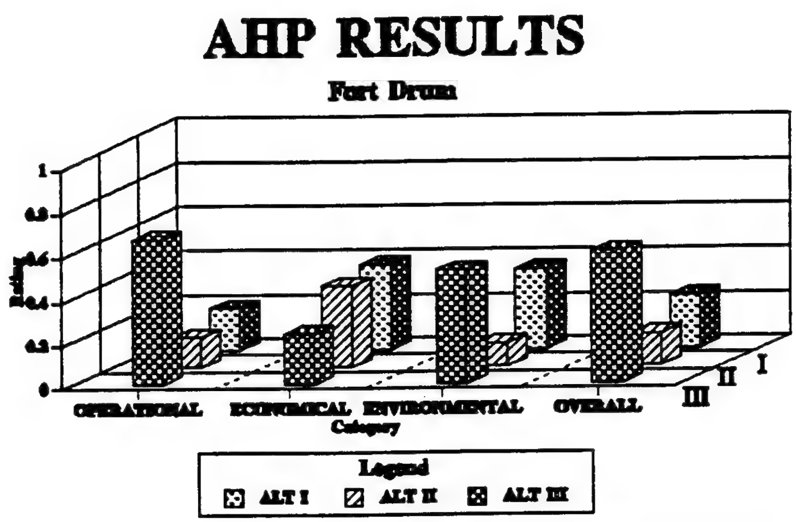
The AHP for Fort Drum produced interesting results. The AHP gave Alternative III a heavy relative weight of 0.603 compared to Alternative I at 0.247. However, the terrain at Fort Drum permits construction at only one location, grid 491785, without Q-D areas extending past the post boundary. Alternative III would require significant upgrading of the primitive road network to the proposed site. These considerations coupled with the fact that the

existing ASP serves Fort Drum very well, argue for future expansion to occur at the existing ASP site.

This raises the question of the high relative weight for Alternative III. A possible explanation for this high weight is that the Fort Drum ammunition managers who provided input for the AHP discounted the scarcity of suitable terrain for underground storage. Given the harsh winters at Fort Drum, it is reasonable to expect the ammunition managers would want total underground storage.

3.9 Recommendations

MTA strongly recommends Alternative I for Fort Drum.



ALT I	0.196	0.393	0.369	0.247
ALT II	0.141	0.374	0.109	0.11
ALT III	0.663	0.233	0.522	0.643

Figure 3 Fort Drum AHP Results

CHAPTER 4
FORT DIX, NEW JERSEY

4.0 Background

MTA, Inc. personnel visited Fort Dix, NJ on November 4-5, 1993 and obtained information concerning the ammunition storage mission. Fort Dix has a robust mission to support active and reserve component elements of the Army, Air Force, Navy, Marine Corps, and Coast Guard. Fort Dix serves as a prime training installation for the Reserve Components. Over 35% of the Army Reserve Components are located within 300 miles of Fort Dix. Also Fort Dix is an ideal mobilization station for Army active and reserve components due to its proximity to McGuire Air Force Base.

4.1 Facts

Fort Dix has the potential to become even more of an asset as a power projection installation because of its proximity to McGuire Air Force Base. McGuire AFB will become the Air Force's east coast mobility center as a result of the base realignment decisions in 1993. McGuire AFB will become even more important as a projection base for deploying forces.

Fort Dix also supports a number of non-DOD activities which require ammunition storage. These activities include the FBI, a Federal prison and New Jersey state prison facilities.

It was apparent to MTA personnel that Fort Dix's existing ammunition supply point (ASP) is well beyond its useful life. Existing ammunition storage bunkers are 1940 vintage with doors which do not allow access for material handling equipment. The existing ASP is located near the installation boundary and is far removed from the training ranges. Presently, ammunition trucks must drive near the populated areas of the installation in order to get to the training ranges.

Fort Dix's flat topography, sandy soil, and high water table level, favor aboveground ammunition storage. The biggest drawback to underground storage is the lack of hills which would permit horizontal tunnelling. For example, the overburden required to prevent surface

disruption and projectiles from an underground explosion would be in the range of 160 to 260 feet for a stored explosive weight of 100,000 to 400,000 pounds respectively. Clearly this type of terrain does not exist at Fort Dix.

There was an approved Military Construction Army (MCA) project to build a new aboveground ASP to be located close to the training areas. However, this was canceled by the Base Realignment and Closure Commission 1991 (BRAC-91) decision to transfer the basic and advanced individual training mission from Fort Dix.

4.2 Alternative I

Alternative I will maintain the existing aboveground facilities and expand to meet future storage needs with similar aboveground structures.

Alternative I is not viable for a number of reasons. The existing ASP is too close to the post boundary for expansion. The civilian community expansion is rapidly approaching. The existing ammunition storage facilities are well beyond their useful life. The existing magazines have no interior lighting. Flood lights must be used for operations at night. This is a major safety concern. Existing facilities are inefficient because of narrow doors which prevent the use of materials handling equipment. All ammunition stores must be moved by hand. Finally, the existing ASP is vulnerable to theft and sabotage.

4.3 Alternative II

Alternative II would retain aboveground storage structures and build underground for future storage requirements.

4.4 Alternative III

This alternative would abandon or demolish the existing aboveground storage facilities and build underground storage.

Alternatives II and III are not viable at Fort Dix because underground ammunition storage is not feasible for the reasons stated above. Thus there is no discussion of advantages or disadvantages for these alternatives.

4.5 Alternative IV

Alternative IV would construct a new aboveground ASP at the location selected by the canceled MCA project (see Annex A).

4.5.1 Advantages

This alternative is the only realistic option for Fort Dix because of the impracticality of underground storage alternatives and the inadequacy of the existing ASP. This alternative is based on the approved plans for the canceled ASP construction project and will satisfy Fort Dix's expanded mission requirements with over 28,000 square feet of space compared to the existing 16,000 square feet. The new aboveground ASP will permit the use of material handling equipment. The site is significantly closer to firing ranges and will preclude hauling ammunition through the populated areas of the post. It solves the problem of encroaching civilian population. Finally, a new aboveground ASP will be significantly more secure compared to the existing ASP.

4.5.2 Disadvantages

Alternative IV has no significant disadvantages except that the Q-D area will use 518 acres in the training area of the installation. The Fort Dix master plan for mobilization does not indicate any planned construction activity which would impinge on this Q-D area.

4.6 Life Cycle Cost - Alternative IV

4.6.1 Present Value

The present value of Alternative IV is computed by adding the cost of design and construction at $11.0 million to the equivalent present value of the annual operating costs of the ASP which is $0.448 million ($0.393 labor + $0.035 million equipment + $0.020 million plant maintenance).

The PV for alternative IV at 5% interest rate is therefore

$11.0 million + PV of annual costs or

$11.0 million + (15.372 x $0.448 million = $17.89 million

The PV for this alternative at 10% interest rate will yield:

$11.0 million + (9.427 x $0.448 million) = $15.22 million

4.6.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $11.0 million) + Annual Operating Costs or

(0.06505 x $11.0 million) + $0.448 = $1.164 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $11.0 million) + Annual Operating Costs or

(0.10608 x $11.0 million) + $0.448 million = $1.615 million per year

4.7 Analytic Hierarchy Process

Since there is only one feasible option, Alternative IV, at Fort Dix, this study will not use the AHP analysis.

4.8 Recommendations

Given the unsuitability of underground ammunition storage construction at Fort Dix and the unacceptable condition of the existing ASP, MTA recommends the Fort Dix build Alternative IV immediately.

Table 3: Fort Dix Life Cycle Cost Analysis (Millions of Dollars)

Method	Alt I	Alt II	Alt III	Alt IV
PV at 5%	N/A	N/A	N/A	17.89
PV at 10%	N/A	N/A	N/A	15.22
EAC at 5%	N/A	N/A	N/A	1.164
EAC at 10%	N/A	N/A	N/A	1.615

CHAPTER 5
FORT KNOX, KENTUCKY

5.0 Background

Fort Knox is located near Radcliffe, KY, 30 miles southwest of Louisville on U.S. Highway 31W. Fort Knox supports the Army Armor Center and School, the headquarters of the Army Recruiting Command, the 194th Armored Brigade, and the 2nd ROTC Region. A total of 10,600 active duty, 1,000 National Guard, and 4,044 Reserve soldiers serve at Fort Knox.

MTA personnel visited Fort Knox on 15-16 November 1993. On 15 November Mr. James Rowlett, ammunition manager for Directorate of Logistics, and Mr. Ed Kisling, the QASAS for Fort Knox, met with MTA personnel to discuss the characteristics of the ammunition support mission at Fort Knox and the operation of the ASP to support that mission.

Mr. Dan Powell, Master Planner of the Department of Public Works, and Mr. Leonard Potter, the Post Safety Officer, joined Mr. Rowlett and Mr. Kisling for a second meeting with MTA personnel on 15 November 1993 to discuss the objectives of MTA's visit to Fort Knox.

5.1 Facts

The ASP at Fort Knox is located on 360 acres of land in the northwest portion of the installation. The active part of the ASP consists of 120 acres and contains a well maintained series of aboveground magazines and supporting buildings and facilities. Some 240 acres of the adjacent old ASP are available for emergency ammunition storage in earth covered magazines during mobilization. The ASP is readily accessible to both commercial trucks and railroad delivery.

The ASP stores the small arms basic load of the 194th Armored Brigade. Larger caliber ammunition for the 194th is stored at depots and will be shipped from the depots for deployment.

The civilian community of Muldraugh, KY borders Fort Knox and blocks expanding the ASP to the southwest. However, the old ASP is located to the northeast of the current ASP and provides a logical place for expansion.

The ASP is well organized for the Fort Knox mission. There are 55,000 square feet of actual ammunition storage space in 26 structures. There are seven Stradley earth covered magazines built in 1988 in addition to the 12 oval arch earth covered magazines built in 1953. There is a large 20,000 square foot small arms ammunition storage building built in 1988, a surveillance and inspection building, and an ammunition storage building with 10 individual magazines. A number of 1942 vintage small earth covered magazines are still in use for miscellaneous storage.

Excellent rail facilities service the ASP at Fort Knox. There is a large rail loading dock for delivery of ammunition at the south end of the ASP. In addition, there is a rail dock at the small arms ammunition building. However, the rail facilities are seldom used except for delivery of 105mm tank ammunition. The rail facilities do, however, give the Fort Knox ASP flexibility in selecting transportation modes and are an asset for mobilization.

Mr. Rowlett indicated there is no present need for additional storage space. However, an unknown factor is the impact of the next round of base closings. Conceivably these closings could increase the ammunition storage mission at Fort Knox.

The ASP is located far from the two new ranges: Yano Tank range and Wilcox Aerial Gunnery ranges. Ammunition haul trucks must travel over 20 miles to these ranges. A proposed railroad line to the Yano range would reduce the ammunition haul problem as well as save considerable wear on the tanks which now must road march to the Yano range. Since an M1A1 tank costs about $80.00 per mile to operate, a railroad line to the Yano range could be an excellent investment.

Mr. Powell observed that the proposed railroad line could cost $40 million and that funding for the railroad would be difficult to obtain. Congress has already spent $25 million for the Yano and Wilcox ranges.

5.2 Alternative I

Alternative I will maintain the current aboveground storage structures and expand aboveground for future storage requirements.

5.2.1 Advantages

Alternative I consolidates ammunition operations at one location and does not require increased staff or material handling equipment. There is no increase in Q-D area and it is the least costly alternative for expansion.

5.2.2 Disadvantages

Alternative I will increase ammunition operations close to the installation boundary and civilian community. This alternative will increase security requirements because of the larger ASP perimeter. Surveillance requirements for Intrusion Detection Systems (IDS) and perimeter fencing and lighting will increase.

Fort Knox ammunition managers did not identify any shortfall in storage capacity to meet the current mission. Thus, there is no pressing need to consider any expansion at the time of this report. However, as the realignment and closure of Army facilities continues, there may be a demand for additional storage space at Fort Knox.

If a need for additional storage space should arise in the future, Alternative I at Fort Knox translates into expanding the active ASP into the old ASP area (240 acres) by refurbishing the 1942 vintage earth covered magazines. This expansion alternative is on-going since the most recent expansion of the ASP has been to refurbish the magazines in the old ASP area at an approximate cost of $100,000 per 1,600 square foot magazine (see Annex A).

5.3 Alternative II

Alternative II will retain the existing aboveground storage structures and build underground storage facilities for future storage requirements. Alternative II may have merit for Fort Knox's current ammunition operations. Underground ammunition storage facilities near the remote Yano tank and Wilcox aerial gunnery ranges would dramatically reduce the ammunition haul distance. Suitable sites for this simple underground storage mode are at grid 075863 for the Yano range and at grid 062020 for the Wilcox range. Both sites are accessible by flat approach roads from major public highways to allow for direct delivery of ammunition from depots.

The underground ammunition storage facilities at the Yano and Wilcox ranges would be designed such that any blast from an incident would directed away from, and contained within, the installation boundaries.

The anticipated 4,000 square feet of underground storage at each of the Yano and Wilcox ranges is a simple chamber connected to an entrance tunnel. Both of the suggested locations have a minimum of 200 feet of rock overburden.

5.3.1 Advantages

This alternative will bring useful ammunition storage facilities closer to the new Yano and Wilcox tank and aerial gunnery ranges. This will reduce ammunition haul distances significantly to these state of the art ranges. Also Alternative II does not increase ammunition storage at the existing ASP.

5.3.2 Disadvantages

The major disadvantage of Alternative II is that the ammunition manager will have multiple ASP sites to operate. This would stretch his already reduced work force. Inherent in multiple ASP sites is the requirement for duplicate material handling equipment. Additional staff may be needed to manage the remote underground storage site under this alternative. Another disadvantage of Alternative II is the concern for security at these remote underground storage sites. Finally, this alternative will use the most real estate of any alternative under consideration.

5.4 Alternative III

Alternative III will abandon or demolish the existing aboveground ammunition storage structures and transfer all operations to an underground storage facility. Alternative III would provide 52,800 square feet of storage to match the capability of the existing ASP. Some considerations for underground storage at Fort Knox are:

Present aboveground ammunition storage is very close to the civilian community.

There is ideal terrain for underground ammunition storage. There are many potential sites for underground storage which would have easy access from the road network and which would have a substantial overburden of rock.

The present ASP is not centrally located to the ranges. A more central location in the vicinity of the Mill Creek Grenade Range (Grid 962922) would be a possible underground storage site and would reduce the haul distance to Yano Tank Range by approximately 7 miles.

Alternative III will release over 1,000 acres of usable terrain which was once within the existing ASP Q-D arcs.

5.4.1 Advantages

The significant advantage of Alternative III is the elimination of the possibility of an incident close to the civilian community and the subsequent ill will such an incident would create. This alternative will improves safety in the military community by minimizing the effects of an explosion through intelligent site selection and design of the underground storage system. This alternative will improve security because there will only be two tunnel entrances to monitor at the underground storage facility compared to multiple monitors for aboveground magazines.

Alternative III reduces grounds maintenance cost for snow removal, grass cutting, road and fencing due to smaller perimeter. This alternative uses the least area and will release the real estate occupied by the existing ASP.

This alternative also uses real estate which has little other value, i.e., hillsides.

5.4.2 Disadvantages

Alternative III has the highest initial cost and abandonment of the existing ASP which serves the Fort Knox mission well. It would be viable only if Army or Department of Defense policy requires increased separation of ammunition facilities from civilian communities over that required by DOD 6055.9-STD standards. Another scenario would be the desire to avoid the possibility of adverse public relations due to an incident at the ASP which is located close to the civilian community of Muldraugh, KY.

5.5. Life Cycle Cost - Alternative I

5.5.1 Present Value

Alternative I at Fort Knox anticipates refurbishing five existing earth covered magazines for $500,000. The present value of this alternative is the sum of the $500,000 initial cost plus the present value of the annual operating costs over the 30 year life of the ASP. The annual operating costs are $0.626 million per year ($0.542 million labor + $0.044 million equipment + $0.040 million plant maintenance).

The PV for alternative I at 5% interest rate is:

$0.500 million + PV of annual costs or

$0.500 million + (15.372 x $0.626 million) = $10.12 million

The PV for this alternative at 10% interest rate will yield

$0.500 million + (9.427 x $0.626 million) = $6.40 million

5.5.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $0.500 million) + Annual Operating Costs or

(0.06505 x \$0.500 million) + \$0.626 = \$0.658 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of \$0.500 million) + Annual Operating Costs or

(0.10608 x \$0.500 million) + \$0.626 million = \$0.679 million per year

5.6 Life Cycle Cost - Alternative II

This alternative will build two underground storage chambers each connected to the face of a hill by an entrance passageway. It will provide 6,400 square feet of storage. The conceptual cost estimate based on a finished unit cost of \$175 per cubic yard for the two storage chambers and \$225 per cubic yard for the entrance tunnel using the drill and blast method is \$1.99 million. Applying the method outlined for Alternative I, the PV and EAC are computed.

5.6.1 Present Value

The PV for alternative II at 5% interest rate is:

\$1.99 million + PV of annual costs or

\$1.99 million + (15.372 x \$0.626 million)= \$11.61 million

The PV for this alternative at 10% interest rate will yield:

\$1.99 million + (9.427 x \$0.626 million) = \$7.89 million

5.6.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of \$1.99 million) + Annual Operating Costs or

(0.06505 x \$1.99 million) + \$0.626 million = \$0.755 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of \$1.99 million) + Annual Operating Costs or

(0.10608 x \$1.99 million) + \$0.626 million = \$0.837 million per year

5.7 Life Cycle Costs - Alternative III

This alternative will build an underground storage chambers system consisting of eight 6,600 square foot chambers arranged in a horse shoe pattern. There is a chamber which connects the two legs of the horse shoe for maintenance activities. The system will provide 24,000 square feet of storage. The conceptual cost estimate based on a finished unit cost of $175 per cubic yard for the two storage chambers and $225 per cubic yard for the entrance tunnel using the drill and blast method is $13.53 million. Applying the method outlined for Alternative I, the PV and EAC are computed.

5.7.1 Present Value

The PV for Alternative III at 5% interest rate is:

$13.53 million + PV of annual costs or

$13.53 million + (15.372 x $0.626 million) = $23.15 million

The PV for this alternative at 10% interest rate will yield:

$13.53 million + (9.427 x $0.626 million) = $19.43 million

5.7.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $13.53 million) + Annual Operating Costs or

(0.06505 x $13.53 million) + $0.626 million = $1.506 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $13.53 million) + Annual Operating Costs or

(0.10608 x $13.53 million) + $0.626 million = $2.061 million per year

Table 4: Fort Knox Life Cycle Cost Analysis (Millions of Dollars)

Method	Alt I	Alt II	Alt III	Alt IV
PV at 5%	10.12	11.61	23.15	N/A
PV at 10%	6.40	7.89	19.43	N/A
EAC at 5%	0.658	0.755	1.506	N/A
EAC at 10%	0.679	0.837	2.061	N/A

5.8 Analytic Hierarchy Process

The AHP analysis at Fort Knox gives overwhelming weight to Alternative III. MTA suspects that the existing ASP's proximity to the civilian community and its remoteness from the new tank and aerial gunnery ranges has forced the selection of the most costly alternative. The AHP has produced the highest relative weight (0.691) of any installation the investigators visited. Ironically, the AHP preferred Alternative II with its partial underground storage near the new ranges over Alternative I which would expand the existing ASP.

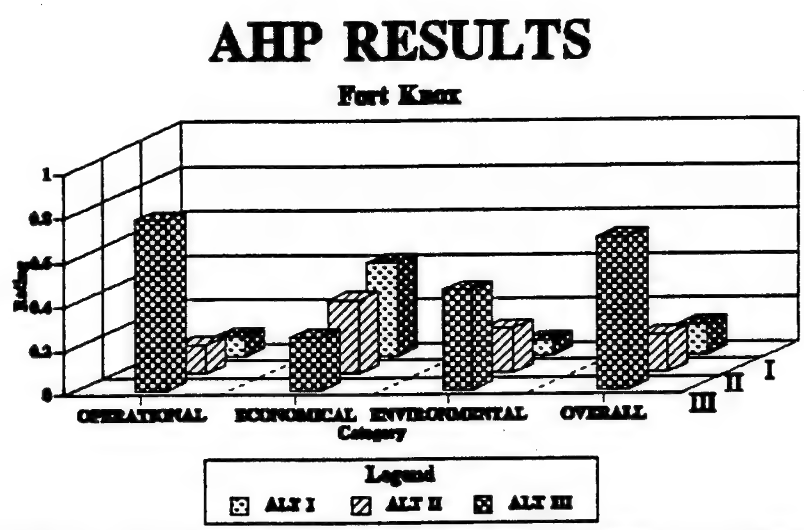
5.9 Recommendation

Fort Knox has an excellent ASP and there is no pressing need for expansion. However, the proximity of the civilian community of Muldraugh, KY to the ASP is a concern and is an argument for relocation of the ASP. While Muldraugh is not within the Q-D arcs, any incident at the ASP would become a major concern to the public. For this reason alone, the Army should consider relocating the ASP to an area less prone to civilian encroachment. The best solution for the problem of civilian encroachment is to relocate the ASP to a more central location at a significant distance from the post boundary. Inherent to this solution is the

central location at a significant distance from the post boundary. Inherent to this solution is the possibility of underground storage. The terrain of Fort Knox favors construction of an underground storage facility because of the lack of suitable flat terrain for conventional aboveground ammunition storage. The Army needs the available flat terrain for tactical training. MTA recognizes that relocation of the ASP to an underground facility is a costly investment ($13.5 million construction cost). However, MTA feels that the advantages inherent in underground storage outweigh the cost burden. MTA anticipates significant advantages with underground storage in security, safety, and maintainability. The AHP validates the observation that the optimum solution is underground storage at this installation.

The most significant aspect of choosing the underground storage option is the recovering of over 1,000 acres of open terrain once occupied by the current ASP.

MTA recommends Fort Knox relocate its ASP to a centrally located underground facility.



ALT I	[illegible]	[illegible]	[illegible]	0.139
ALT II	0.131	[illegible]	[illegible]	0.17
ALT III	0.774	[illegible]	[illegible]	0.691

Figure 4 Fort Knox AHP Results

CHAPTER 6
FORT CAMPBELL, KENTUCKY

6.0 Background

Fort Campbell is located fifty miles northwest of Nashville, near Clarksville, Tennessee (off Route 41A, on the Kentucky-Tennessee border). Fort Campbell is headquarters for the 101st Airborne Division (Air Assault) with 24,000 active-duty soldiers.

MTA personnel visited Fort Campbell on November 17-18, 1993. Mr. Dickie Quick (ASP Manager), and Mr. Bill Lewis (QASAS) were the escorts for the visit. Don Pendleton (ISSD), Dick Huser (DPW/ESD), and Frank Bryan (Installation Safety) also provided valuable information for this report.

6.1 Facts

Fort Campbell's present ASP consists of 60 standard earth-covered magazines, a temporary vehicle holding area, a railhead safe haven, a Conex area, and an ammunition surveillance building. An abandoned ASP consisting of 32 earth-covered magazines is adjacent to the current ASP. Also abandoned are 25 underground storage facilities that once housed special weapons. The underground storage facilities were built in the early fifties and were part of the old US Navy Clarksville Base.

The Fort Campbell ASP is well organized, managed, and maintained. The original ASP was built in 1941. However, all 60 standard earth-covered magazines were built in the 1952-53 time frame and are in excellent condition. The standard earth-covered magazines have interior lights. The magazines' double doors allow the use of material handling equipment.

The 101st Airborne Division Commander requires the ASP to store the basic load of ammunition for all weapons systems. All of the earth-covered magazines contain portions of the basic load of the division and supporting units as well as training ammunition. The installation ammunition

manager stated that the pace of the division training had accelerated in 1993 and that the division was using large amounts of training ammunition compared to usage in 1992.

The ASP is located in the southeast quadrant of the post. Its location requires long haul distances to many of the ranges. Ammunition types range from small arms to 155mm.

Fort Campbell also supports Reserve Component training and will support the active duty Special Operations Forces which have arrived from other installations as a result of base realignments and closures. Fort Campbell managers believe that these new requirements will require fifteen additional standard earth-covered magazines which already exist in the inactive part of the ASP.

There are 32 abandoned earth-covered magazines which can be refurbished to meet DOD standards for approximately $100,000 each. There are 25 underground ammunition storage bunkers which are currently used for general storage by individual units and are not under control of the ammunition manager. These underground magazines which were designed for special weapons storage and maintenance offer additional ammunition storage possibilities.

The ASP was well built, organized and maintained. There is a 24 hour guard at the ASP manned by division soldiers. There is an adjacent small arms ammunition storage area for CONEX and other type containers. Here, units have round-the-clock access to their ammunition which has been previously issued to the units. This allows maximum flexibility in ammunition and unit training operations.

Additionally, the post is installing intrusion detection systems on 29 of the standard earth-covered magazines.

6.2 Alternative I

Alternative I will retain the existing aboveground storage and expand with aboveground storage facilities for future needs. Fort Campbell has the enviable option of expanding into well constructed magazines of the former Navy Clarksville Base. These magazines can be

refurbished at a unit cost of $100,000. Based on the ammunition manager's estimate, Fort Campbell will need 15 additional magazines at 2,500 square feet each to meet the future ammunition storage requirements. This will provide an additional 37,500 square feet of storage (see Annex A).

6.2.1 Advantages

Alternative I is the least costly of the alternatives and is the most feasible. Expansion at the existing facility will have little impact, if any, on the Q-D area of the existing ASP.

6.2.2 Disadvantages

Alternative I does not have any significant disadvantages.

6.3 Alternative II

Alternative II will retain existing aboveground storage facilities and expand underground for future needs. Fort Campbell is in excellent position to consider this alternative. There are 25 2,000 square foot underground ammunition magazines adjacent to the active ASP which could be restored to ammunition storage usage. This would require expansion of the perimeter of the ASP facility as well as a much larger Q-D area going from the eastward facing tunnel openings. Nineteen of the existing underground magazines will provide an additional 38,000 square feet of storage.

6.3.1 Advantages

The advantage of Alternative II is that Fort Campbell could gain the advantages of underground ammunition storage at relatively very little cost. The existing underground ammunition storage chambers appear to be ideal candidates for refurbishment.

6.3.2 Disadvantages

This alternative will require a large expansion of the security measures to encompass the linear area of the underground magazines. This will require additional real estate be set aside for a larger Q-D area for safety.

6.4 Alternative III

Alternative III will require abandoning the existing aboveground ammunition facilities and building new underground facilities.

Fort Campbell has no pressing need to abandon its excellent existing aboveground and underground facilities. The location of the existing ASP is such that the Q-D area does not impact military or civilian activities. Consequently, there is no advantage to constructing a large capacity underground ammunition storage facility at Fort Campbell.

6.5 Life Cycle Cost Analysis

No life cycle cost analysis was calculated for Fort Campbell because there is no need for expansion of ammunition storage capability.

6.6 Analytic Hierarchy Process

Likewise, there was no AHP analysis performed because there is no need for expansion.

6.7 Recommendations

There is no need for additional ammunition storage space at Fort Campbell. There is no Q-D problem. For these and other reasons, MTA recommends implementation of Alternative I on

an as needed basis. Fort Campbell enjoys the advantage of at will expansion of its aboveground ammunition storage into the unused portion of the ASP for a relatively refurbishing cost of $100,000 per earth covered magazine. Alternative I is the most efficient use of the former ASP area.

Fort Campbell could also opt for Alternative II by simply refurbishing the existing underground storage chambers of the former Clarksville Navy Base. This alternative could provide over 30,000 square feet of storage. However, it would also greatly extend the requirement for security measures and extend the Q-D area toward an industrial area of the post. Considering the cost of extending the security perimeter to the line of underground magazines and the cost of replacing the inadequate doors and other items, Alternative II falls short compared to Alternative I.

CHAPTER 7
FORT HUACHUCA, ARIZONA

7.0 Background

Fort Huachuca is located near Sierra Vista, 70 miles southeast of Tucson off State Route 90. Major activities at Fort Huachuca are the U.S. Army Intelligence Center, the U.S. Army Information Systems Command, the 11th Signal Brigade, the Joint Operations Training Site and the U.S. Army Electronic Proving Ground. 5,700 active duty soldiers and 5,600 civilian employees work at Fort Huachuca. Over 35 reserve component units train at Fort Huachuca annually. In addition, Fort Huachuca supports Joint Task Force Six (JTF-6) and Explosive Ordnance Disposal activities. An additional 1,700 soldiers who presently train at Fort Devens will move to Fort Huachuca by September 1995.

MTA personnel visited Fort Huachuca on 6-9 December 1993. On 7 December MTA personnel met with Les Burgess, QASAS; James P. O'Brien, Ammunition Manager of the Directorate of Logistics; John Hill, Master Planner of the Directorate of Engineering and Housing, and Don Gallo, Acting Director of Logistics to discuss the purpose of MTA's visit and the nature of the ammunition support mission at Fort Huachuca.

7.1 Facts

The existing ASP consists of 19 magazines constructed in 1942-43 with 8,676 square feet of usable space. The ASP is obsolete in every sense. Four magazines are outside the ASP proper and presently are not in use. These 4 magazines were recently refurbished and will be used temporarily to meet storage requirements until a new ASP is built. A family housing area is located within 1500 feet of the ASP. This is within the fragmentation hazard distance for high explosives in storage. This proximity of family housing precludes effective use of a number of magazines in the ASP proper. Another concern is the road within 300 feet of the ASP. Any mass detonation of explosives in storage would endanger unprotected personnel on the road.

Safety and security are concerns. The location of the existing ASP requires that vehicles carrying ammunition and explosives travel through populated areas of the installation. There is no lighting for night operations. The Intrusion Detection System is operational on only two of the 19 magazines. The magazine doors are too narrow to allow use of Material Handling Equipment (MHE). This requires potentially dangerous and inefficient handling of ammunition at the magazines.

The situation at the existing ASP is complicated by the requirement to store ammunition outside during peak training periods. This is a dangerous practice since there is a high incidence of lightning strikes in the area. Because of the lack of storage space and the desire to minimize outside storage of ammunition, only a small portion of required ammunition can be kept on hand. This constrains unit readiness.

Most significantly, there is no dedicated ammunition surveillance facility at Fort Huachuca. The ammunition personnel do perform this vital function in other covered areas at the ASP.

The location of the existing ASP at the base of a hill allows the run off waters from the numerous violent thunderstorms to cause erosion of the sandy top soil at the site. The run off waters are powerful enough to break down the security fence.

In short, there is an imminent threat to life and property caused by the design and location of the existing ASP. To meet the current and the projected near term ammunition storage requirements, Fort Huachuca needs over 16,000 square feet of usable magazine storage space as well as over 12,000 square feet of supporting facilities for ammunition surveillance, administration, a guardhouse, an inert materials storage yard and a safe haven truck holding area.

The Master Planner, Mr. John Hill, described the on-going project to replace the existing ASP during the 7 December meeting. He told the MTA personnel that the Training and Doctrine Command Commander had placed the proposed new aboveground ASP at Fort Huachuca in the FY 97 Military Construction Army funding plan. The final approval for this new construction will be in June 1994. He was very emphatic that our effort to analyze the ammunition storage

mode options not delay in any way the on-going process to build the designated aboveground replacement ASP.

7.2 Alternative I

Alternative I would expand the existing ASP. For the reasons stated previously, this alternative is not a viable option.

7.3 Alternative II

This alternative would keep the existing ammunition storage facilities in use and expand to underground to meet future storage needs. Again, this alternative is not ideal because it retains the existing ASP with its safety problems.

7.4 Alternative III

Alternative III will abandon the existing ASP and build new ammunition storage facilities underground. This is a very attractive alternative for the combination of factors unique to Fort Huachuca. MTA personnel selected a number of potential candidates for underground storage during their visit.

7.4.1 Advantages

Alternative III will eliminate the safety problem of the existing ASP by placing the new underground facility away from populated areas of the installation. The new facility would avoid the danger of transporting ammunition through populated areas. It would also significantly reduce the haul distance to the training ranges. This underground facility will be immune to the dangers of the water run off from the severe thunderstorms and significantly less exposed to the associated lightning strikes. It will also allow use of the large amount of real estate now

occupied by the ASP for more appropriate purposes. This alternative will have a significantly less impact on the fragile desert environment than the other feasible alternative (Alternative IV).

7.4.2 Disadvantages

Alternative III is the most costly and would cause some difficulty among the master planners at Fort Huachuca who desire the quickest fix to their ammunition storage problem. MTA understands the difficulty in proposing delay in the funding process to authorize the proposed aboveground ASP (Alternative IV). However, MTA feels that Fort Huachuca has the most to gain from underground ammunition storage and would do well to consider the advantages of Alternative III before committing to Alternative IV.

7.5 Alternative IV

As mentioned above, this alternative would construct a new above ground ASP at a site remote from the populated areas of the installation (see Annex A). This alternative is well underway to becoming reality in the funding process.

7.5.1 Advantages

Alternative IV is a quick, comfortable solution to the pressing need for a new ASP at Fort Huachuca. It is well along in the commander's planning process and has the support of the master planners of the installation. It will solve the safety and operational problems. If nothing happens to derail the funding process, an above ground ammunition storage facility will serve Fort Huachuca in 1999.

7.5.2 Disadvantages

There are no disadvantages to Alternative IV except to note that Alternative III will use significantly less real estate.

7.6 Life Cycle Cost - Alternative II

7.6.1 Present Value

There will be no life cycle cost analysis for Alternative I because it is not a viable option at Fort Huachuca.

Alternative II would provide 8,000 square feet of underground storage in two chambers and retain the existing ASP. As mentioned previously, the existing ASP must be replaced. The life cycle cost analysis for Alternative II is presented here for comparison purposes only.

The present value of Alternative II is computed by adding the cost of constructing and designing ($2.24 million) to the present value of the stream of annual operating expenses, $0.220 million per year ($0.175 million labor + $0.025 million equipment + $0.020 million plant maintenance)

The PV for alternative II at 5% interest rate is:

$2.24 million + PV of annual costs or

$2.24 million + (15.372 x $0.22 million) = $5.62 million

The PV for this alternative at 10% interest rate will yield:

$2.24 million + (9.427 x $0.22 million) = $4.31 million

7.6.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $2.24 million) + Annual Operating Costs or

(0.06505 x $2.24 million) + $0.22 million = $0.365 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $2.24 million) + Annual Operating Costs or

(0.10608 x $2.24 million) + $0.22 million = $0.457 million per year

7.7 Life Cycle Cost - Alternative III

This alternative will build an underground storage chambers system consisting of six 4,000 square foot chambers arranged in a horse shoe pattern. There is a chamber which connects the two legs of the horse shoe for maintenance activities. The system will provide 24,000 square feet of storage. The conceptual cost estimate based on a finished unit cost of $175 per cubic yard for the two storage chambers and $225 per cubic yard for the entrance tunnel using the drill and blast method is $8.07 million. Applying the method outlined for Alternative I, the PV and EAC is similarly computed.

7.7.1 Present Value

The PV for alternative III at 5% interest rate is:

$8.07 million + PV of annual costs or

$8.07 million + (15.372 x $0.22 million) = $11.45 million

The PV for this alternative at 10% interest rate will yield:

$8.07 million + (9.427 x $0.22 million) = $10.14 million

7.7.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $8.07 million) + Annual Operating Costs or

(0.06505 x $8.07 million) + $0.22 million = $.745 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $8.07 million) + Annual Operating Costs or

(0.10608 x $8.07 million) + $0.22 million = $1.076 million per year

7.8 Life Cycle Cost - Alternative IV

Alternative IV will provide a replacement aboveground ASP at a programmed cost of $6.8 million.

7.8.1 Present Value

Present Value of Alternative IV at 5% is:
$6.80 million + (15.372 x $0.22 million) = $10.18 million

The present value of the alternative at 10% is:
$6.80 million + (9.427 x $0.22 million) = $8.87 million

7.8.2 Equivalent Annual Cost

The equivalent annual cost of Alternative IV at 5% is:
(EAC of $6.8 million) + $0.22 million or
(0.06505 x $6.8 million) + $0.22 million = $0.662 million

The EAC at 10% is:
(0.10608 x $6.8 million) + $0.22 million = $0.941 million

Table 5: Fort Huachuca Life Cycle Cost Analysis (Millions of Dollars)

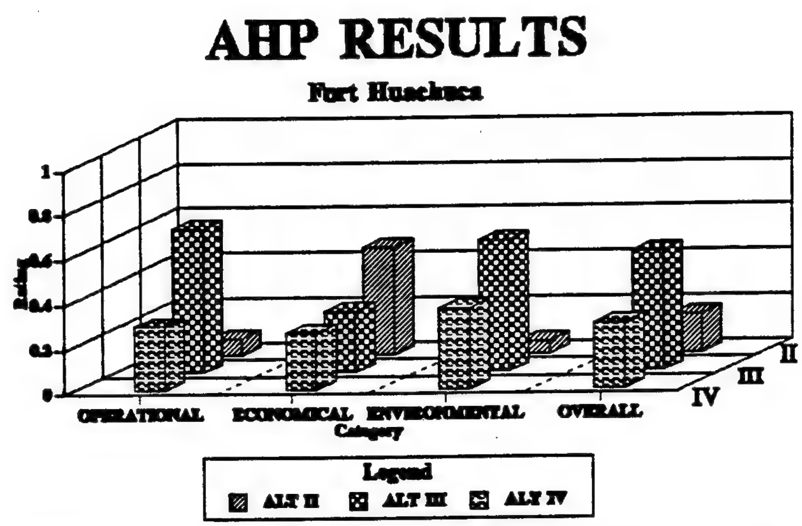
Method	Alt I	Alt II	Alt III	Alt IV
PV at 5%	N/A	5.62	11.45	10.18
PV at 10%	N/A	4.31	10.14	8.87
EAC at 5%	N/A	0.365	0.745	0.662
EAC at 10%	N/A	0.457	1.076	0.941

7.9 Analytical Hierarchy Process

The AHP produced a heavy preference for Alternative III followed by an expected high preference for Alternative IV. The AHP did not consider Alternative I and did penalize Alternative II because that alternative would retain the unacceptable existing ASP.

7.10 Recommendations

MTA recommends Alternative III as the preferred solution for Fort Huachuca. MTA recommends that the Fort Huachuca leadership continue with the funding request and modify the design to build an underground ASP.



ALT II	[illegible]	0.475	[illegible]	0.174
ALT III	0.641	0.273	0.593	0.533
ALT IV	0.265	0.252	0.362	0.293

Figure 5 Fort Huachuca AHP Results

CHAPTER 8
FORT CARSON, COLORADO

8.0 Background

Fort Carson is located six miles south of Colorado Springs off Interstate 25 and State Highway 115. Fort Carson is headquarters for the 4th Infantry Division (Mechanized) and the 43rd Support Group. The 10th Special Forces Group (Airborne) will be relocated to Fort Carson from Fort Devens, MA. Fort Carson currently has 16,188 active duty soldiers, 2,000 civilians, and 200 Reserve Component soldiers.

MTA personnel visited Fort Carson on 10-13 December 1993. Ed Whitworth (QASAS) and Andrew Romero (Ammunition Manager) were the escorts for the visit. Dick Hall (Director of Public Works), Ken Wrightsman (DPW), and Don Bauermeister (Safety Officer) also provided valuable information for this report.

8.1 Facts

Fort Carson's current ASP has twenty reinforced concrete oval earth covered magazines. There are four concrete pads, two general storehouses, two ammunition huts, and two small arms magazines. Fort Carson has an Ammunition Holding Area (AHA) three miles from the ASP. The administration and field office buildings complete the ASP. Built in the late sixties and mid-eighties, the ammunition storage magazines are in excellent condition. The ten foot wide doors on the magazines allow for easy access to the ammunition.

Fort Carson managers indicated that the arrival of the 10th Special Forces Group, a brigade size unit, is a major addition to the requirement for ammunition storage. There is no plan for expanding the existing the ASP.

The terrain at Fort Carson is relatively open and rolling. There are a number of possible underground ammunition storage sites on the western border of the installation. One limitation

is the lack of a central location suitable for underground storage which would significantly reduce ammunition haul distances to the ranges on the southern part of the post. On the other hand, Fort Carson borders civilian community of Colorado Springs on the north. As such, any incident at the existing aboveground ASP would cause an adverse reaction among the community despite of the fact that the ASP meets and exceeds all Q-D requirements.

8.2 Alternative I

This alternative would expand the ammunition storage capability by expanding aboveground at the existing ASP for future storage needs (see Annex A).

8.2.1 Advantages

This alternative will allow expansion of up to five earth covered Stradley type magazines within the existing perimeter of the ASP. No additional security measures are necessary except for any intrusion detection systems at the new magazines. There will be no increase in Q-D area required for this alternative.

8.2.2 Disadvantages

The only disadvantage to this alternative is the remote possibility that an incident in this aboveground ASP would cause concern in the urban community of Colorado Springs and cause embarrassment to the Army in a community with high profile Air Force and Unified Command Activities (Air Force Academy and Space Command).

8.3 Alternative II

This alternative would store future ammunition in underground facilities while retaining the existing aboveground ASP.

8.3.1 Advantages

Alternative II would bring a significant portion of the ammunition storage closer to the southern training ranges. It would provide the ammunition managers with flexibility to respond to unique storage requirements as well.

8.3.2 Disadvantages

This alternative does not provide any real advantages over the expansion of storage within the existing ASP as in Alternative I. It would require additional Q-D area in addition to the Q-D area of the existing ASP. It would also require increased security systems to manage a remote site in addition to the existing ASP.

8.4 Alternative III

This alternative would abandon or demolish the existing aboveground ASP and replace it with underground storage. Suitable terrain exists in the northwest quadrant of Fort Carson to build underground ammunition storage facilities. However, this proposed underground storage site will not reduce the extensive haul distance to the southern ranges to any extent.

8.4.1 Advantages

There are few advantages to Alternative III compared to Alternative I at Fort Carson other than the public relations considerations about an explosion in the aboveground ASP mentioned above.

8.4.2 Disadvantages

The main disadvantage of this alternative is the high cost of design and construction and the abandonment of an excellent aboveground facility.

8.5 Life Cycle Cost - Alternative I

8.5.1 Present Value

Alternative I would provide for three Stradley magazines of 2000 square feet each to be built within the existing ASP. This would cost approximately $1.00 million. The present value of this alternative is determined by adding the $1.00 million initial cost to the present value of the stream of annual operating expenses of $0.501 million per year ($0.437 million labor + $0.044 equipment + $0.020 million plant maintenance).

The PV for alternative I at 5% interest rate is:

$1.00 million + PV of annual costs or

$1.00 million + (15.372 x $0.501) = $8.70 million

The PV for this alternative at 10% interest rate will yield:

$1.00 million + (9.427 x $0.501 million) = $5.72 million

8.5.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $1.00 million) + Annual Operating Costs or

(0.06505 x $1.00 million) + $0.501 = $0.566 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $1.00 million) + Annual Operating Costs or

(0.10608 x $1.00 million) + $0.501 million = $0.607 million per year

8.6 Life Cycle Cost - Alternative II

This alternative will build two underground storage chambers each connected to the face of a hill by an entrance passageway. It will provide 6,400 square feet of storage. The conceptual

cost estimate based on a finished unit cost of $175 per cubic yard for the two storage chambers and $225 per cubic yard for the entrance tunnel using the drill and blast method is $1.99 million. Applying the method outlined for Alternative I, the PV and EAC is similarly computed.

8.6.1 Present Value

The PV for alternative II at 5% interest rate is:

$1.99 million + PV of annual costs or

$1.99 million + (15.372 x $0.501 = $9.69 million

The PV for this alternative at 10% interest rate will yield:

$1.99 million + (9.427 x $0.501 million) = $6.71 million

8.6.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $1.99 million) + Annual Operating Costs or

(0.06505 x $1.99 million) + $0.501 = $0.630 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $1.99 million) + Annual Operating Costs or

(0.10608 x $1.99 million) + $0.501 million = $0.712 million per year

8.7 Life Cycle Cost - Alternative III

This alternative will build an underground storage chambers system consisting of ten 6,600 square foot chambers arranged in a horse shoe pattern. There is a chamber which connects the two legs of the horse shoe for maintenance activities. The system will provide 66,000 square feet of storage. The conceptual cost estimate based on a finished unit cost of $175 per cubic yard for the two storage chambers and $225 per cubic yard for the entrance tunnel using the drill and blast method is $16.50 million. Applying the method outlined for Alternative I, the PV and EAC are computed.

8.7.1 Present Value

The PV for alternative III at 5% interest rate is:

$16.50 million + PV of annual costs or

$16.50 million + (15.372 x $0.501 = $24.20 million

The PV for this alternative at 10% interest rate will yield:

$16.50 million + (9.427 x $0.501 million) = $21.22 million

8.7.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $16.50 million) + Annual Operating Costs or

(0.06505 x $16.50 million) + $0.501 = $1.57 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $16.50 million) + Annual Operating Costs or

(0.10608 x $16.50 million) + $0.501 million = $2.251 million per year

Table 6: Fort Carson Life Cycle Cost Analysis (Millions of Dollars)

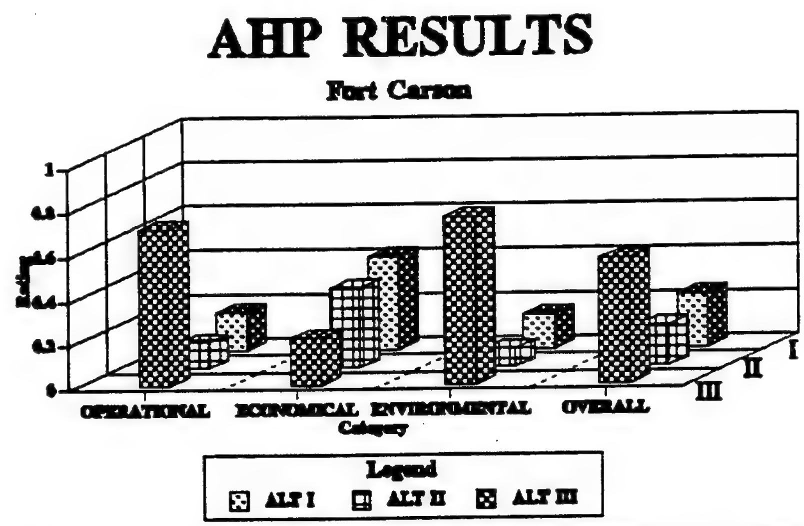
Method	Alt I	Alt II	Alt III	Alt IV
PV at 5%	8.70	9.69	24.20	N/A
PV at 10%	5.72	6.71	21.22	N/A
EAC at 5%	0.566	0.630	1.574	N/A
EAC at 10%	0.607	0.712	2.251	N/A

8.8 Analytic Hierarchy Process

The AHP gives significant weight (0.565) to the underground storage alternative because the ammunition managers gave operational and safety considerations their highest priority. This is not surprising. This caused the AHP to give extra weight to the Alternative III which has the highest operational and safety value of the alternatives under consideration. The relatively high weight for Alternative I (0.249) would have a higher value if the ammunition managers gave the economic consideration a higher value.

8.9 Recommendations

MTA recommends Alternative I as the best solution to the future demand for ammunition storage at Fort Carson.



ALT I	0.177	0.424	0.142	0.249
ALT II	0.118	0.362	0.063	0.186
ALT III	0.705	0.214	0.795	0.566

Figure 6 Fort Carson AHP Results

CHAPTER 9
YAKIMA TRAINING CENTER, WASHINGTON

9.0 Background

Yakima Training Center is located 160 miles southeast of Seattle on Interstate Highway 82. Yakima Training Center consists of 408 square miles of rolling high desert terrain. The Army will add another 150 square miles to the north which will expand the Training Center up to Interstate Highway 90. The Columbia River defines the eastern boundary. Interstate Highway 82 is the western boundary. State Highway 82 roughly defines the southern boundary.

Yakima Training Center is a sub-post of Fort Lewis, WA and supports the brigade size training maneuvers of the 9th Infantry Division as well as wide variety of other military forces which include both Active and Reserve Components of the U.S. Army, Marines Corps Reserve, as well as allied forces (U.K., Canadian, Australian and Japanese). The additional 150 square miles of land will allow a two brigade task force to train and maneuver.

Every U.S. Army weapon system except PATRIOT Air Defense Missile can be fired at Yakima Training Center. This includes the MLRS training round.

9.1 Facts

The ASP at Yakima Training Center is marginal and was constructed in the mid 1950's. The ASP consists of 10 earth covered magazines with 13,780 square feet and one 6000 square foot wooden warehouse. The total covered storage area of the ASP consists of 19,780 square feet. There is one outside storage pad (25 feet x 50 feet) for MLRS ammunition in an adjacent fenced area.

It is significant that 30% of the covered storage area is occupied by unserviceable ammunition waiting transportation to depot. The Army has not funded the transportation needed to return

this large amount of unserviceable ammunition to depot. This stockpiling of unserviceable ammunition at the Yakima ASP detracts significantly from the efficiency of the ASP operations.

Yakima's ASP has a grounds maintenance problem. There are weeds, tall grasses, and tumble weeds which require constant cutting or removal. The large accumulation of weeds and brush is a significant fire hazard.

Yakima Training Center has terrain features which will permit underground ammunition storage. The significant high ground to the northeast of the existing ASP is one potential site which would minimize disruption of current ammunition operations, minimize environmental impact, and minimize the real estate required for the Q-D area. The Army gives considerable attention to the ecosystems at Yakima Training Center. (The environmental office reports directly to the commander). Any aboveground construction of a new ASP could cause major disruption to the habitat of a number of endangered and threatened flora and fauna at Yakima Training Center.

9.2 Alternative I

Alternative I would expand the existing aboveground ASP with similar aboveground magazines for future storage needs. This alternative would require the expansion of the perimeter security fencing lighting, and road system (see Annex A).

9.2.1 Advantages

Alternative I is the least costly and would not increase the impact on the environment significantly.

9.2.2 Disadvantages

Alternative I would continue the use of the marginal existing ammunition storage magazines. Also, any expansion of the existing ASP could present a Q-D problem since the existing Q-D arcs are already very close to the post boundary.

9.3 Alternative II

Alternative II will retain the existing aboveground storage and provide for underground expansion to meet future needs.

9.3.1 Advantages

Alternative II would provide for covered storage for Yakima's projected needs. There are no other significant advantages since the existing marginal ASP would stay in operation.

9.3.2 Disadvantages

The major disadvantage of Alternate II is the expansion to multiple ASP sites which will stretch the ammunition section's labor force very thin. This alternative will not relieve the grounds maintenance problems of the existing ASP.

9.4 Alternative III

This alternative will abandon or demolish the existing ASP and construct underground storage facilities.

9.4.1 Advantages

Alternative III eliminates the grounds maintenance problem of the existing ASP. It provides constant year round temperature storage and frees up a significant amount of real estate now occupied by the existing ASP for other uses. This alternative has the least impact on the fragile desert environment.

9.4.2 Disadvantages

Alternative III is the most costly but only marginally so compared with Alternative IV's aboveground new ASP facility.

9.5 Alternative IV

Alternative IV will build a replacement aboveground ASP at a new site and will abandon the existing ASP.

9.5.1 Advantages

Alternative IV can be designed quickly through the use of standard magazine designs.

9.5.2 Disadvantages

This alternative will be the most disruptive to the environment by far. It will require a significant Q-D area and cost only a little less than the preferred Alternative III which would give complete underground storage.

9.6 Life Cycle Cost - Alternative I

9.6.1 Present Value

Alternative I would expand the existing ASP with five Stradley magazines and provide approximately 10,000 square feet of aboveground storage at a conceptual cost of $1.84 million. The present value of Alternative I is computed by adding the value of the design and construction $1.84 million to the present value of the stream of annual operating costs $0.366 million ($0.326 million labor + $0.025 million equipment + $0.015 million plant maintenance).

The PV for alternative I at 5% interest rate is:

$1.84 million + PV of annual costs or

$1.84 million + (15.372 x $0.366 million) = $7.47 million

The PV for this alternative at 10% interest rate will yield:

$1.84 million + (9.427 x $0.366 million) = $5.29 million

9.6.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $1.84 million) + Annual Operating Costs or

(0.06505 x $1.84 million) + $0.366 = $0.486 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $1.84 million) + Annual Operating Costs or

(0.10608 x $1.84 million) + $0.366 million = $0.561 million per year

9.7 Life Cycle Cost - Alternative II

This alternative will build two underground storage chambers each connected to the face of a hill by an entrance passageway. It will provide 8,000 square feet of storage. The conceptual cost estimate based on a finished unit cost of $175 per cubic yard for the two storage chambers and $225 per cubic yard for the entrance tunnel using the drill and blast method is $2.24 million. Applying the method outlined for Alternative I, the PV and EAC are computed.

9.7.1 Present Value

The PV for alternative II at 5% interest rate is:

$2.24 million + PV of annual costs or

$2.24 million + (15.372 x $0.366 million = $7.87 million

The PV for this alternative at 10% interest rate will yield:

$2.24 million + (9.427 x $0.366 million) = $5.69 million

9.7.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $2.24 million) + Annual Operating Costs or

(0.06505 x $2.24 million) +$0.366= $0.512 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $2.24 million) + Annual Operating Costs or

(0.10608 x $2.24 million) + $0.366 million = $0.604 million per year

9.8 Life Cycle Cost - Alternative III

This alternative will build an underground storage chambers system consisting of six 4,000 square foot chambers arranged in a horse shoe pattern. There is a chamber which connects the two legs of the horse shoe for maintenance activities. The system will provide 24,000 square feet of storage. The conceptual cost estimate based on a finished unit cost of $175 per cubic yard for the two storage chambers and $225 per cubic yard for the entrance tunnel using the drill and blast method is $8.07 million. Applying the method outlined for Alternative I, the PV and EAC are computed.

9.8.1 Present Value

The PV for alternative III at 5% interest rate is:

$8.07 million + PV of annual costs or

$8.07 million + (15.372 x $0.366) = $13.70 million

The PV for this alternative at 10% interest rate will yield:

$8.07 million + (9.427 x $0.366 million) = $11.52 million

9.8.2 Equivalent Annual Cost

The EAC at 5% interest rate is calculated as follows:

(EAC of $8.07 million) + Annual Operating Costs or

(0.06505 x $8.07 million) + $0.366 = $.891 million per year

The EAC at 10% interest rate is similarly computed:

(EAC of $8.07 million) + Annual Operating Costs or

(0.10608 x $8.07 million) + $0.366 million = $1.222 million per year

9.9 Life Cycle Cost - Alternative IV

Alternative IV will provide a new ASP and abandon the existing ASP. The conceptual cost of the replacement aboveground ASP is $6.79 million.

9.9.1 Present Value

Present value at 5% is:

$6.79 million + (PV of $0.366 million) or
$6.79 million + (15.372 x $0.366 million) = $12.42 million

PV of Alternative IV at 10% is:
$6.79 million + (9.427 x $0.366 million) = $10.24 million

9.9.2 Equivalent Annual Cost - Alternative IV

The EAC of Alternative IV at 5% is:

(EAC of $6.79 million + $0.366 million or
(0.06505 x $6.79 million) + $0.366 million = $0.808 million

The EAC at 10% is:
(EAC of $6.79 million) + $0.366 million or
(0.10608 x $6.79 million) + $0.366 million = $1.09 million

9.10 Analytic Hierarchy Process

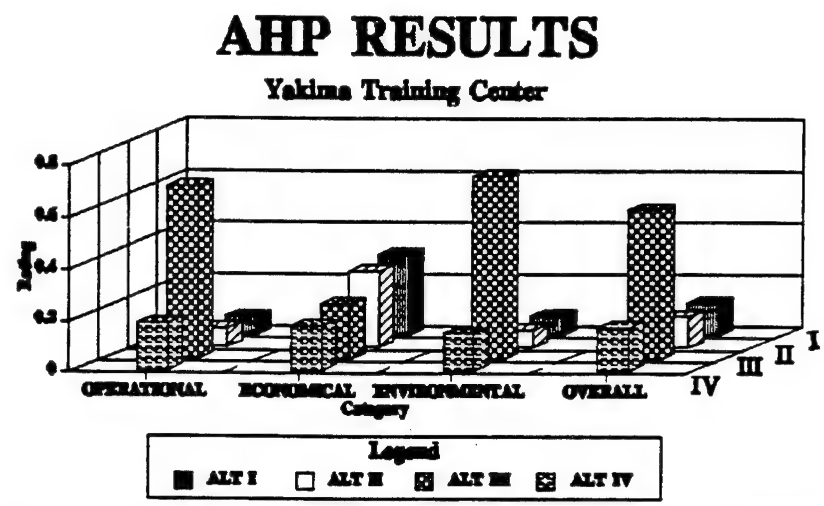
The AHP gave a clear preference to Alternative III. The AHP gave nearly equal low weights to the three other alternatives. This indicates that Alternative IV has a significant advantage over all the other alternatives.

Table 7: Yakima Training Center Life Cycle Cost Analysis (Millions of Dollars)

Method	Alt I	Alt II	Alt III	Alt IV
PV at 5%	7.47	7.87	13.70	12.42
PV at 10%	5.29	5.69	11.52	10.24
EAC at 5%	0.486	0.512	0.891	0.808
EAC at 10%	0.561	0.604	1.222	1.09

9.11 Recommendations

MTA recommends Alternative III as the most effective and efficient option for Yakima Training Center.



ALT I	0.073	0.314	0.075	0.127
ALT II	0.074	0.284	0.048	0.121
ALT III	0.687	0.218	0.707	0.58
ALT IV	0.166	0.177	0.13	0.173

Figure 7 Yakima Training Center AHP Results

ANNEX A

REAL ESTATE

QUANTITY - DISTANCE

ENCUMBRANCES

REAL ESTATE ENCUMBRANCE AND REAL ESTATE IMPACT TABLES

The real estate encumbrance and impact tables present the amount of real estate each ammunition storage alternative requires. The real estate encumbrance table displays the total acreage of the actual storage site, plus the Quantity-Distance acres. For example, at Fort McCoy, WI Alternative I will require 184 acres of land. This acreage requirement is in addition to the real estate already occupied by the existing ASP. Since the existing ASP already requires 461 acres, the addition of Alternate I will add another 184 acres, requiring a total of 645 acres (461 acres + 184 acres). The 645 acres are shown on the real estate encumbrance table. Similarly, Alternative III at Fort McCoy, WI has 6.16 acres for the underground storage site plus 118 acres for the Q-D safety area. Thus, Alternative III uses 125 acres of real estate.

The real estate encumbrance table shows the actual acres used for each alternative. Again, at Fort McCoy, WI, the existing ASP uses 461 acres. Alternative I will require 645 acres while Alternative II will require 588 acres (461 acres + 127 acres). Since Alternative III and IV are independent of the existing ASP real estate usage, choosing either of these alternatives would release the 461 acres currently allocated to the existing ASP. Thus, the net real estate encumbrance of Alternative III is only 125 acres and the net real estate impact is a net gain of 336 acres for Fort McCoy (461 acres from the existing ASP, less 125 acres for the Alternative III site, yields a gain of 336 acres for Fort McCoy).

It is obvious that the underground storage Alternative III offers the most real estate gain to an installation. This real estate impact should be a prime consideration at those installations which have constraints on real estate. This study did not attempt to determine the value of the real estate which would be available for other uses but it is important to consider that all Army land has value to the extent to which it contributes to the mission. In many cases the opportunity cost of real estate is very high and the decision makers should give heavy weight to the amount of real estate savings underground storage affords.

Table A-1.1 : Fort McCoy Real Estate Encumbrance (Acres)

Alternative	Alt I	Alt II	Alt III	Alt IV
Site	0.60	1.32	6.16	2.51
Q-D Area	183	125	118	387
Total Acreage	184	127	125	390

Table A-1.2 : Fort McCoy Net Real Estate Impact (Acres)

Alternative	Existing	Alt I	Alt II	Alt III	Alt IV
Existing	-461	-645	-588	336	71
Alternative I		———	57	520	225
Alternative II			———	463	198
Alternative III				———	196
Alternative IV					———

Table A-2.1 : Fort Drum Real Estate Encumbrance (Acres)

Alternative	Alt I	Alt II	Alt III	Alt IV
Site	0.0	1.22	12.42	N/A
Q-D Area	0.0	133	99	N/A
Total Acreage	0.0	135	113	N/A

Table A-2.2 : Fort Drum Net Real Estate Impact (Acres)

Alternative	Existing	Alt I	Alt II	Alt III	Alt IV
Existing	-496	-496	-631	383	N/A
Alternative I		————	-631	383	N/A
Alternative II			————	518	N/A
Alternative III				————	N/A
Alternative IV					————

Table A-3.1 : Fort Dix Real Estate Encumbrance (Acres)

Alternative	Alt I	Alt II	Alt III	Alt IV
Site				
Q-D Area				
Total Acreage	N/A	N/A	N/A	518

Table A-3.2 : Fort Dix Net Real Estate Impact (Acres)

Alternative	Existing	Alt I	Alt II	Alt III	Alt IV
Existing	-441	N/A	N/A	N/A	-77
Alternative I		———			
Alternative II			———		
Alternative III				———	
Alternative IV					———

Table A-4.1 : Fort Knox Real Estate Encumbrance (Acres)

Alternative	Alt I	Alt II	Alt III	Alt IV
Site	0.0	1.22	10.27	N/A
Q-D Area	1151	133	100	N/A
Total Acreage	1151	135	111	N/A

Table A-4.2 : Fort Knox Net Real Estate Impact (Acres)

Alternative	Existing	Alt I	Alt II	Alt III	Alt IV
Existing	-1151	-1151	-1286	1040	N/A
Alternative I		————	-1286	1040	N/A
Alternative II			————	1175	N/A
Alternative III				————	N/A
Alternative IV					————

Table A-5.1 : Fort Huachuca Real Estate Encumbrance (Acres)

Alternative	Alt I	Alt II	Alt III	Alt IV
Site	N/A	1.32	6.16	3.74
Q-D Area	N/A	125	118	319.3
Total Acreage	N/A	127	125	324

Table A-5.2 : Fort Huachuca Net Real Estate Impact (Acres)

Alternative	Existing	Alt I	Alt II	Alt III	Alt IV
Existing	-446	N/A	-573	321	122
Alternative I		———	N/A	N/A	N/A
Alternative II			———	448	249
Alternative III				———	247
Alternative IV					———

Table A-6.1 : Fort Carson Real Estate Encumbrance (Acres)

Alternative	Alt I	Alt II	Alt III	Alt IV
Site	0.0	1.22	12.34	N/A
Q-D Area	0.0	133	95	N/A
Total Acreage	0.0	135	108	N/A

Table A-6.2 : Fort Carson Net Real Estate Impact (Acres)

Alternative	Existing	Alt I	Alt II	Alt III	Alt IV
Existing	-945	-945	-1080	837	N/A
Alternative I		————	-1080	837	N/A
Alternative II			————	972	N/A
Alternative III				————	N/A
Alternative IV					————

Table A-7.1 : Yakima Training Center Real Estate Encumbrance (Acres)

Alternative	Alt I	Alt II	Alt III	Alt IV
Site	0.60	1.32	6.16	2.51
Q-D Area	183	125	118	387
Total Acreage	184	127	125	390

Table A-7.2 : Yakima Training Center Net Real Estate Impact (Acres)

Alternative	Existing	Alt I	Alt II	Alt III	Alt IV
Existing	-619	-803	-746	494	229
Alternative I		———	57	678	413
Alternative II			———	621	356
Alternative III				———	354
Alternative IV					———

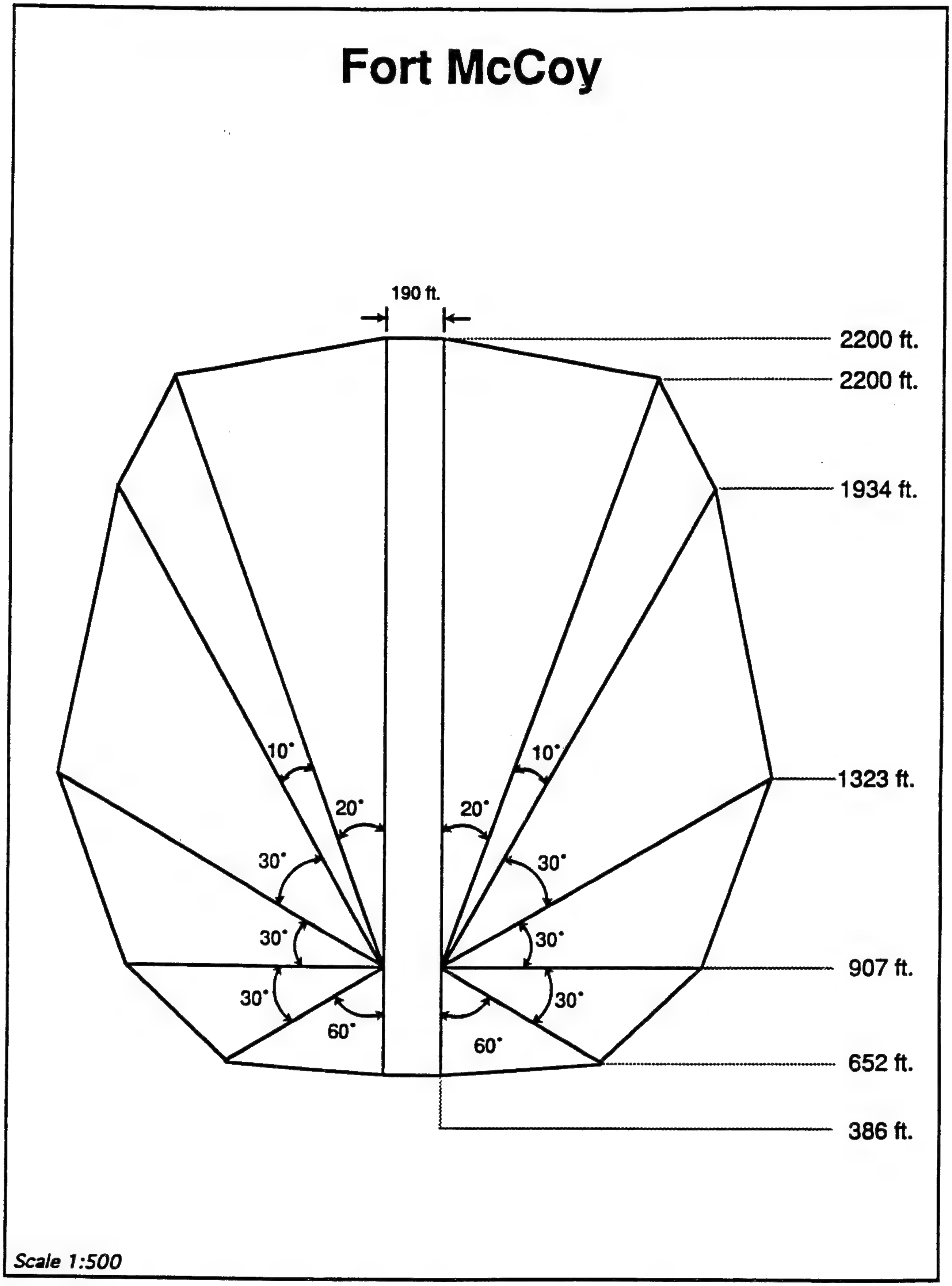


Figure A-1. Real Estate Encumbrance for Underground Storage Alternative II

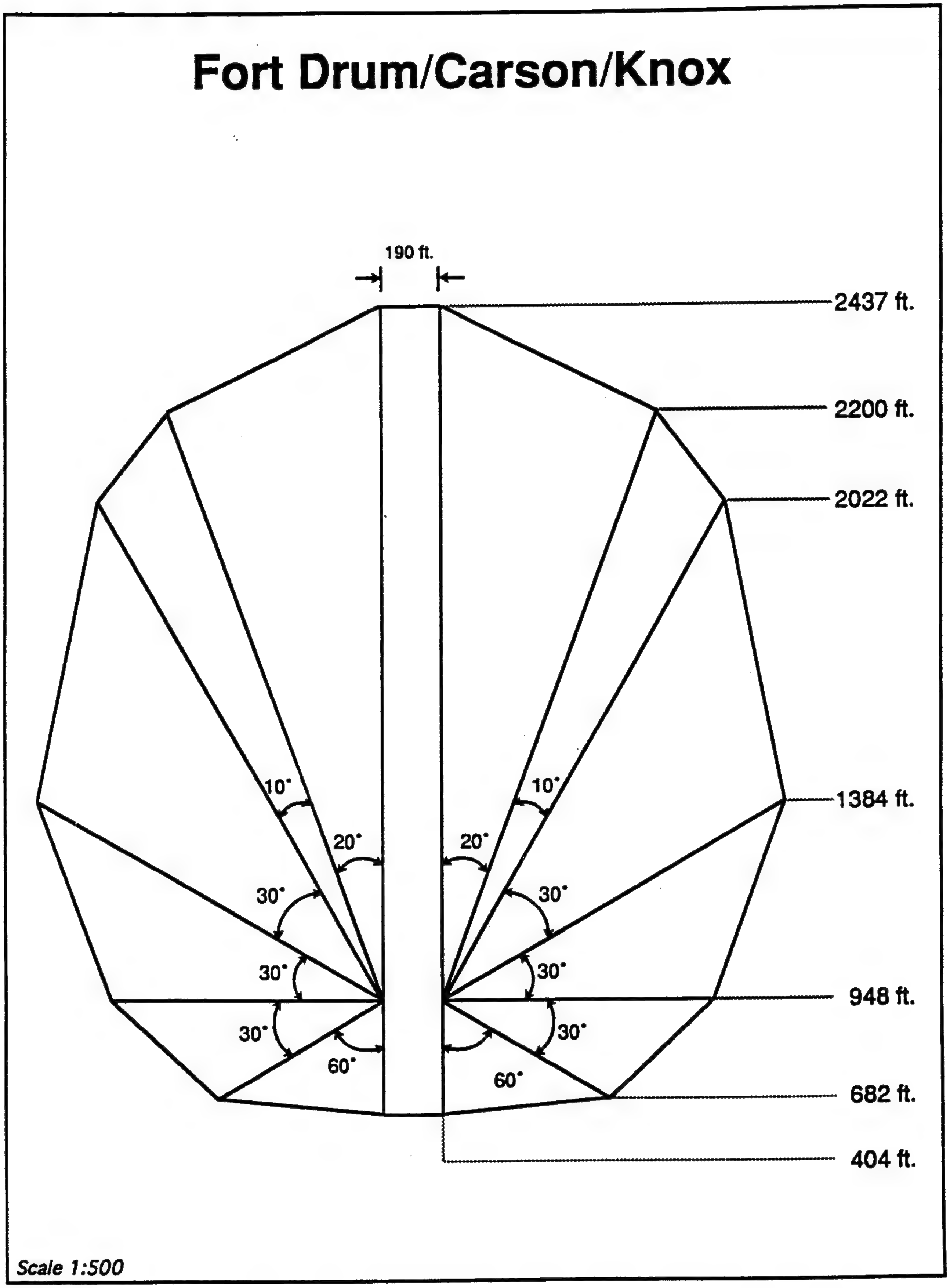


Figure A-2. Real Estate Encumbrance for Underground Storage Alternative II

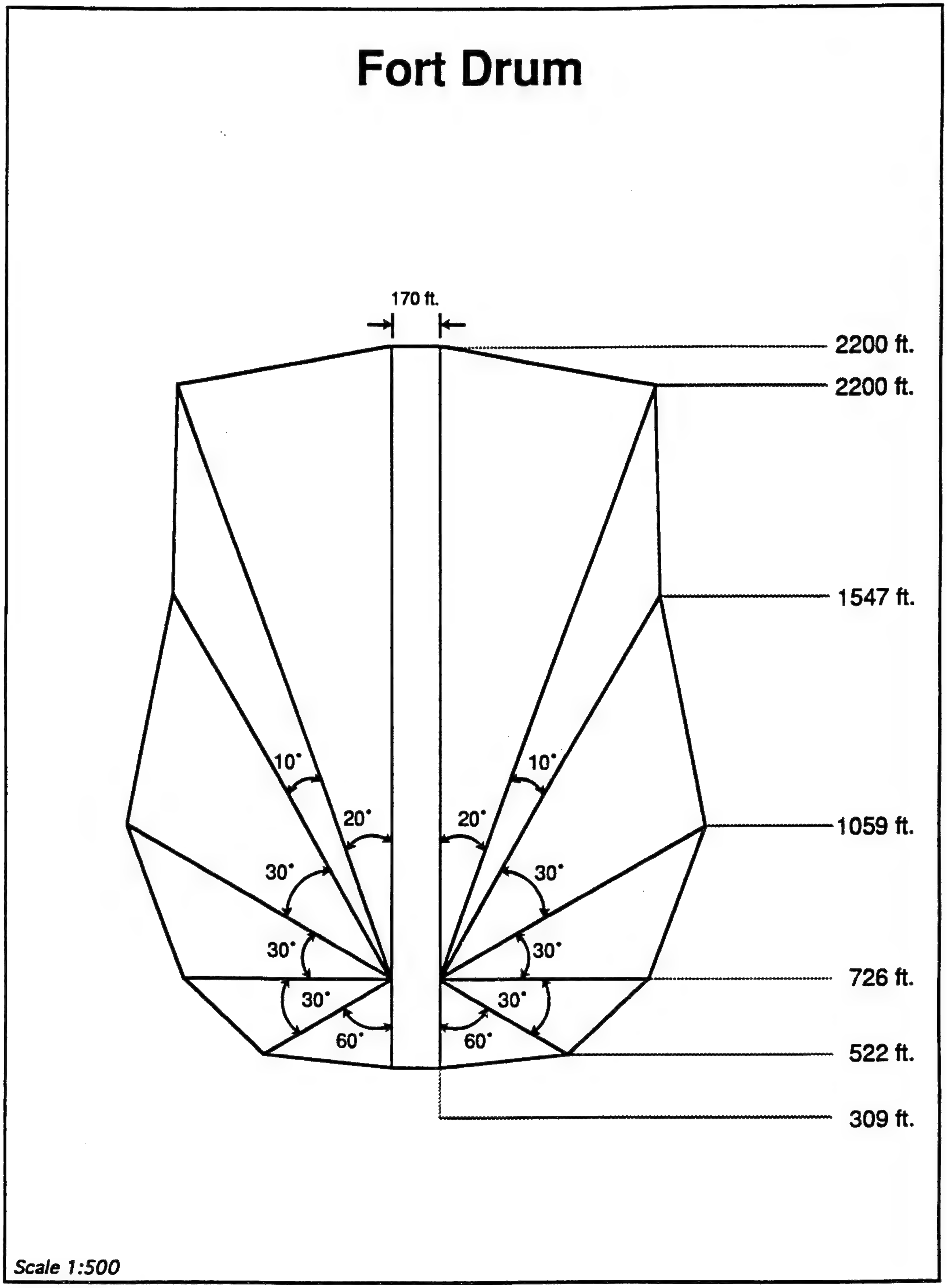


Figure A-3. Real Estate Encumbrance for Underground Storage Alternative III

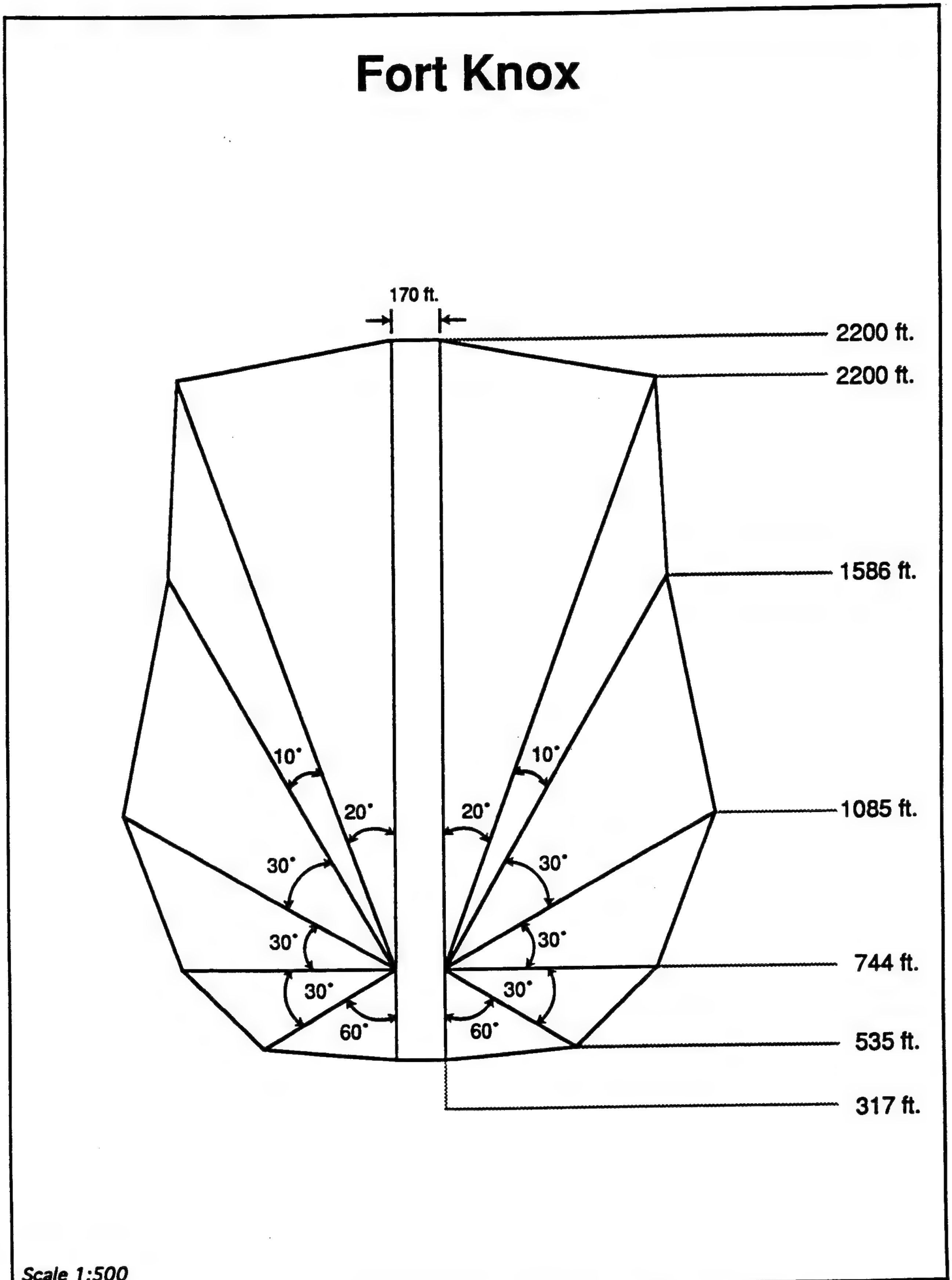


Figure A-4. Real Estate Encumbrance for Underground Storage Alternative III

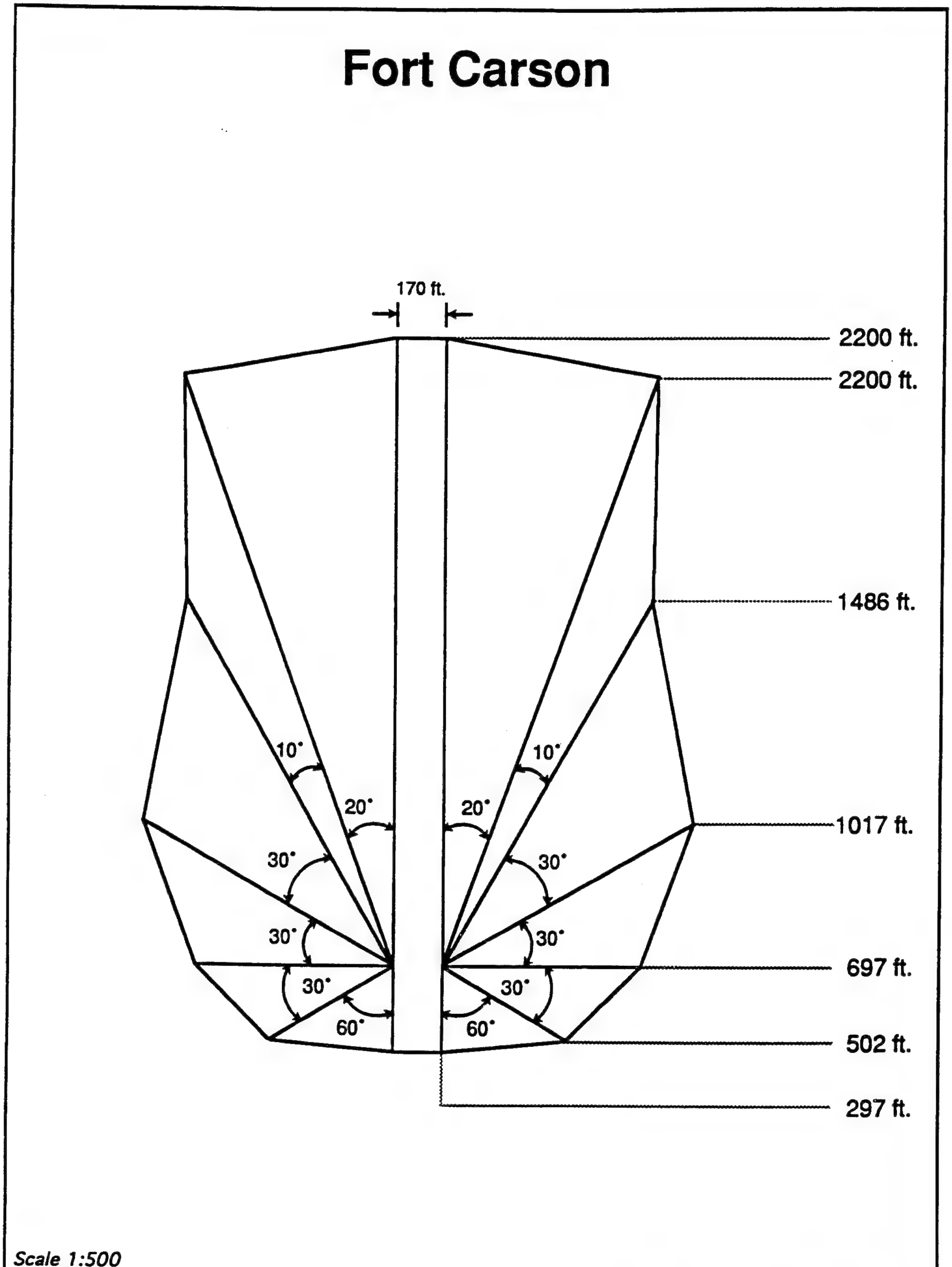


Figure A-5. Real Estate Encumbrance for Underground Storage Alternative III

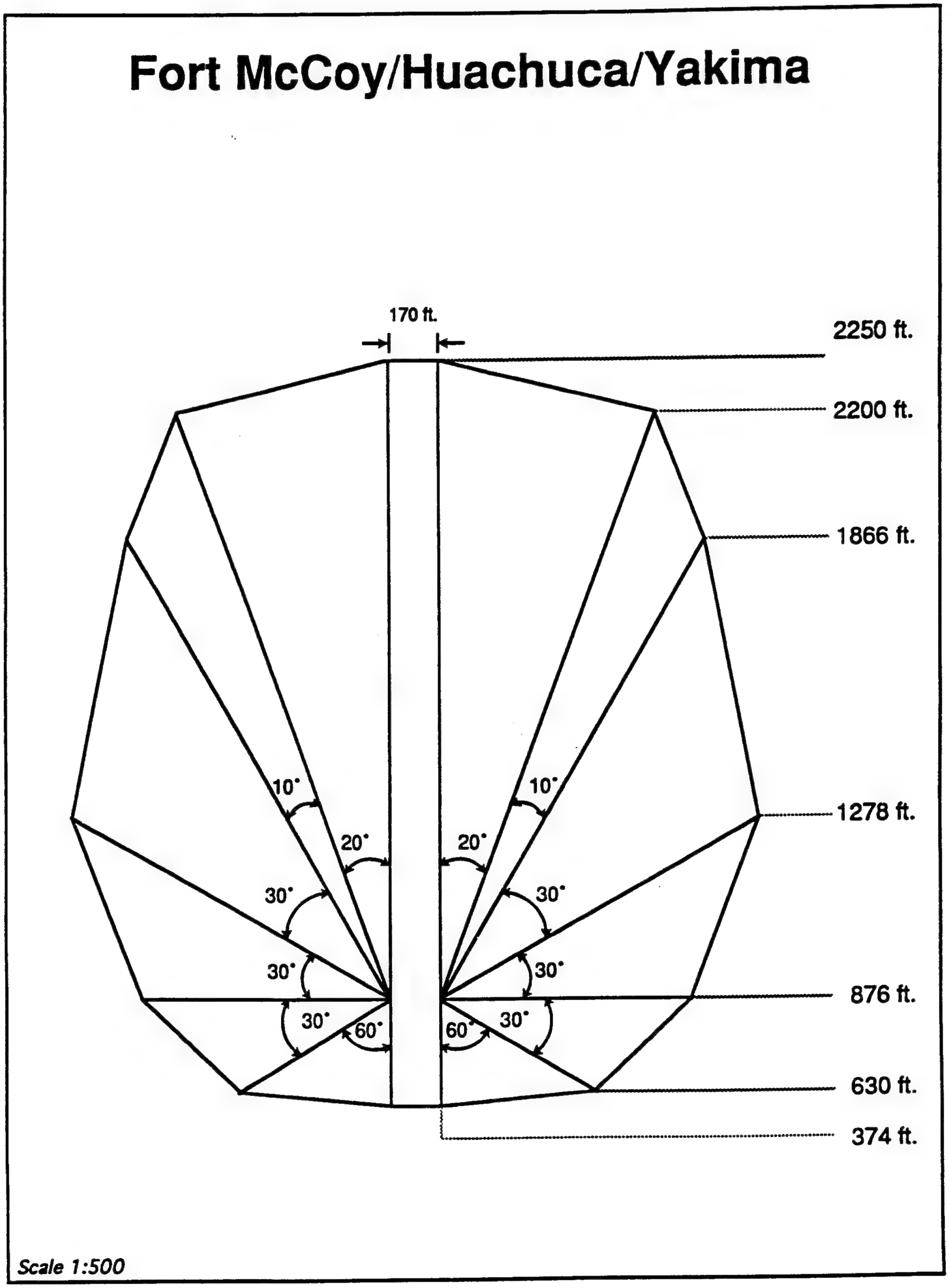


Figure A-6. Real Estate Encumbrance for Underground Storage Alternative III

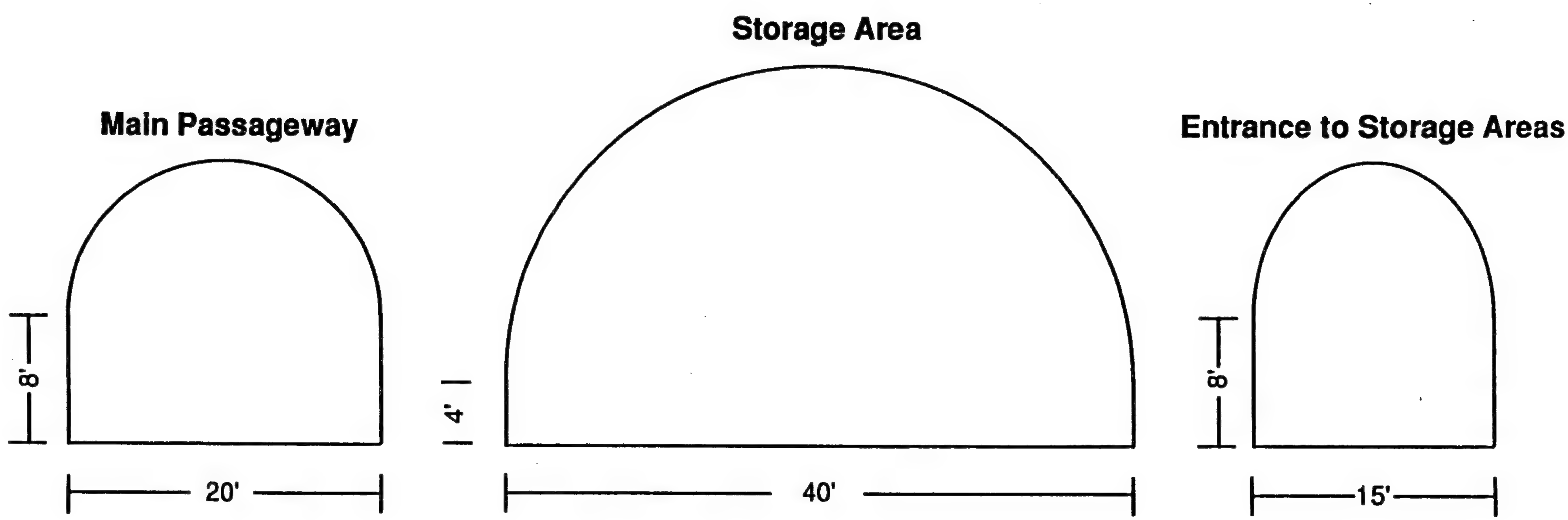


Figure A-7. Underground Storage Cross Section

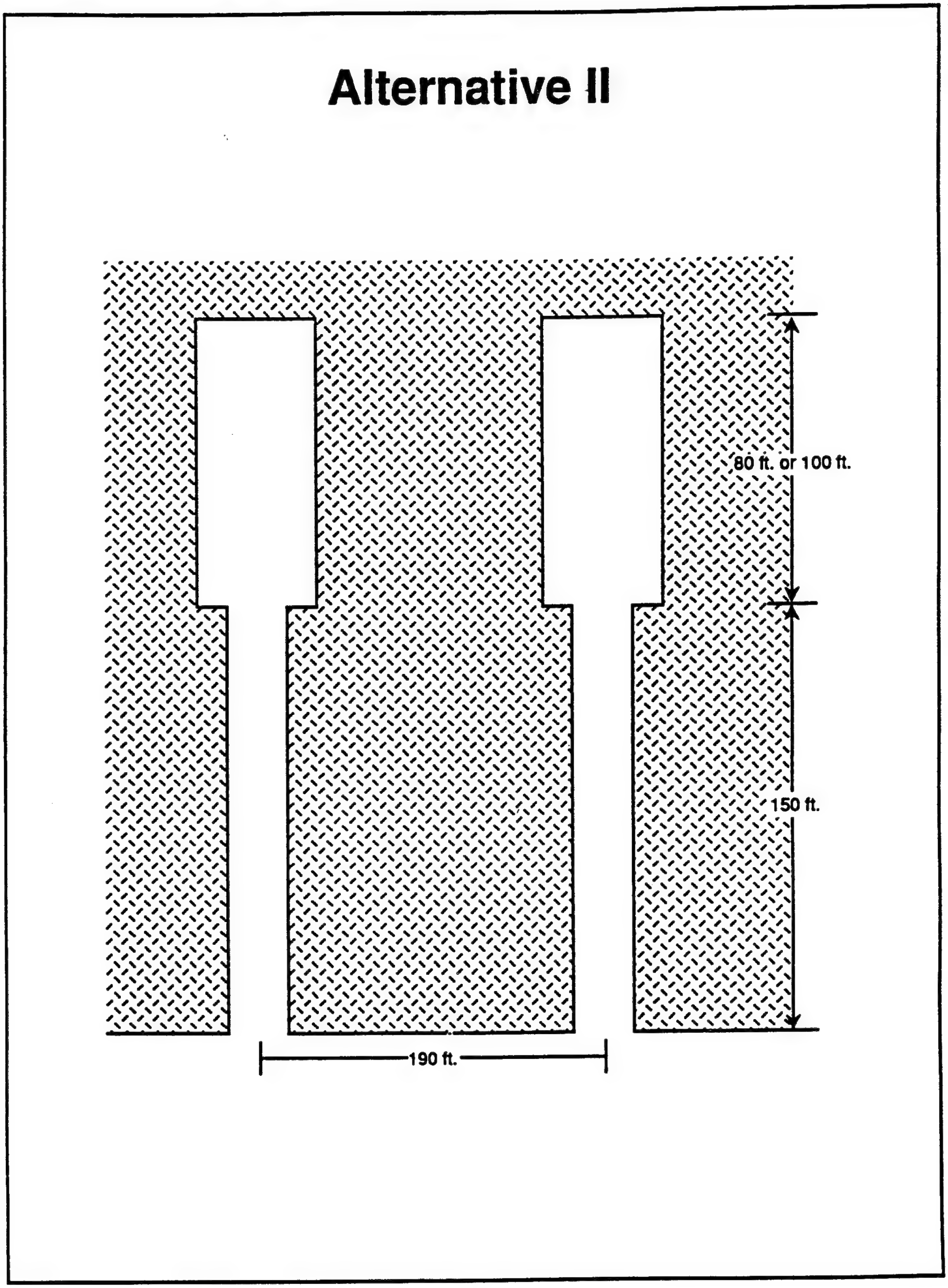


Figure A-8. Plan View Alternative II

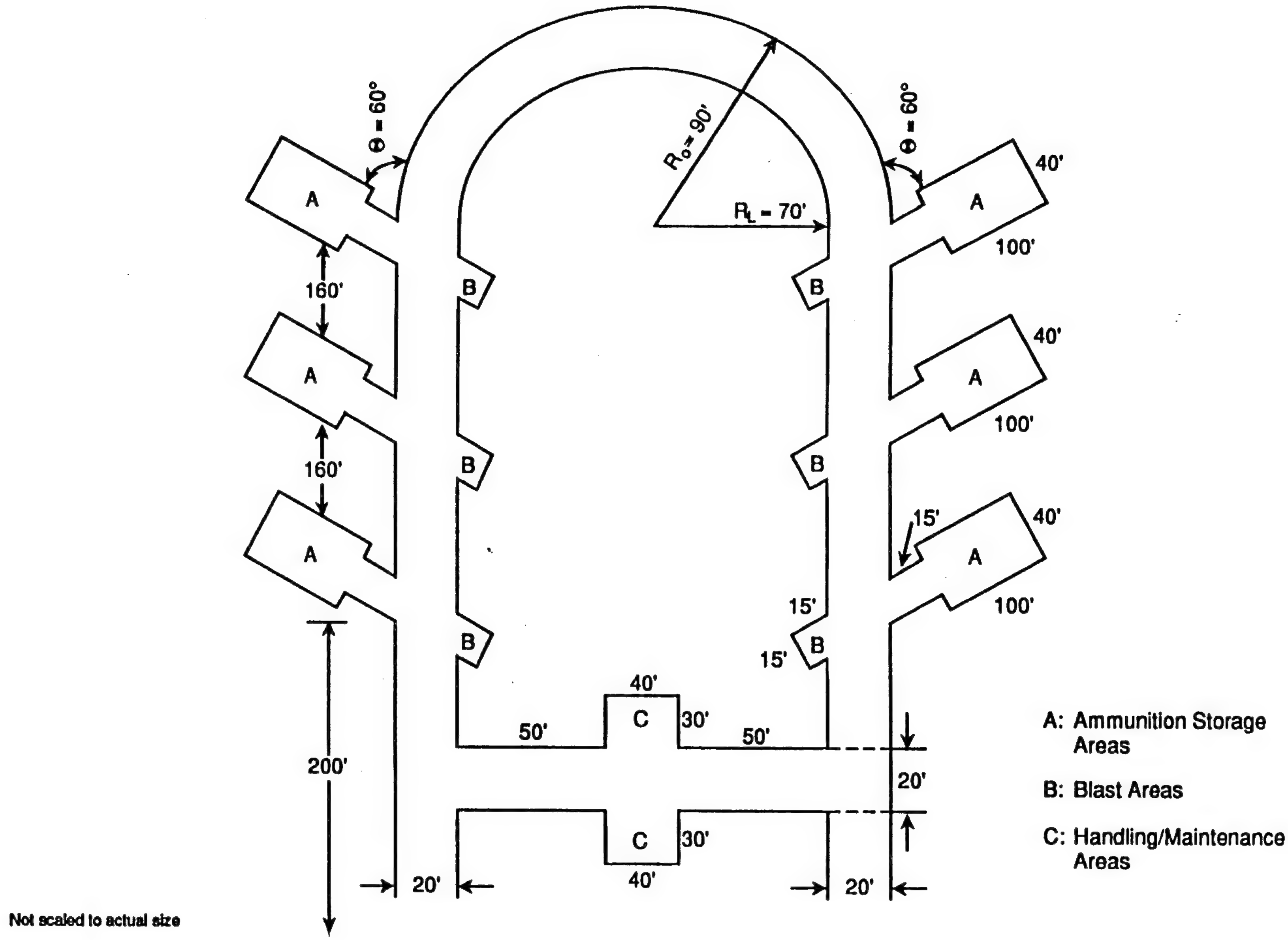


Figure A-9. Alternative III: Fort McCoy, Fort Huachuca, Yakima Training Center

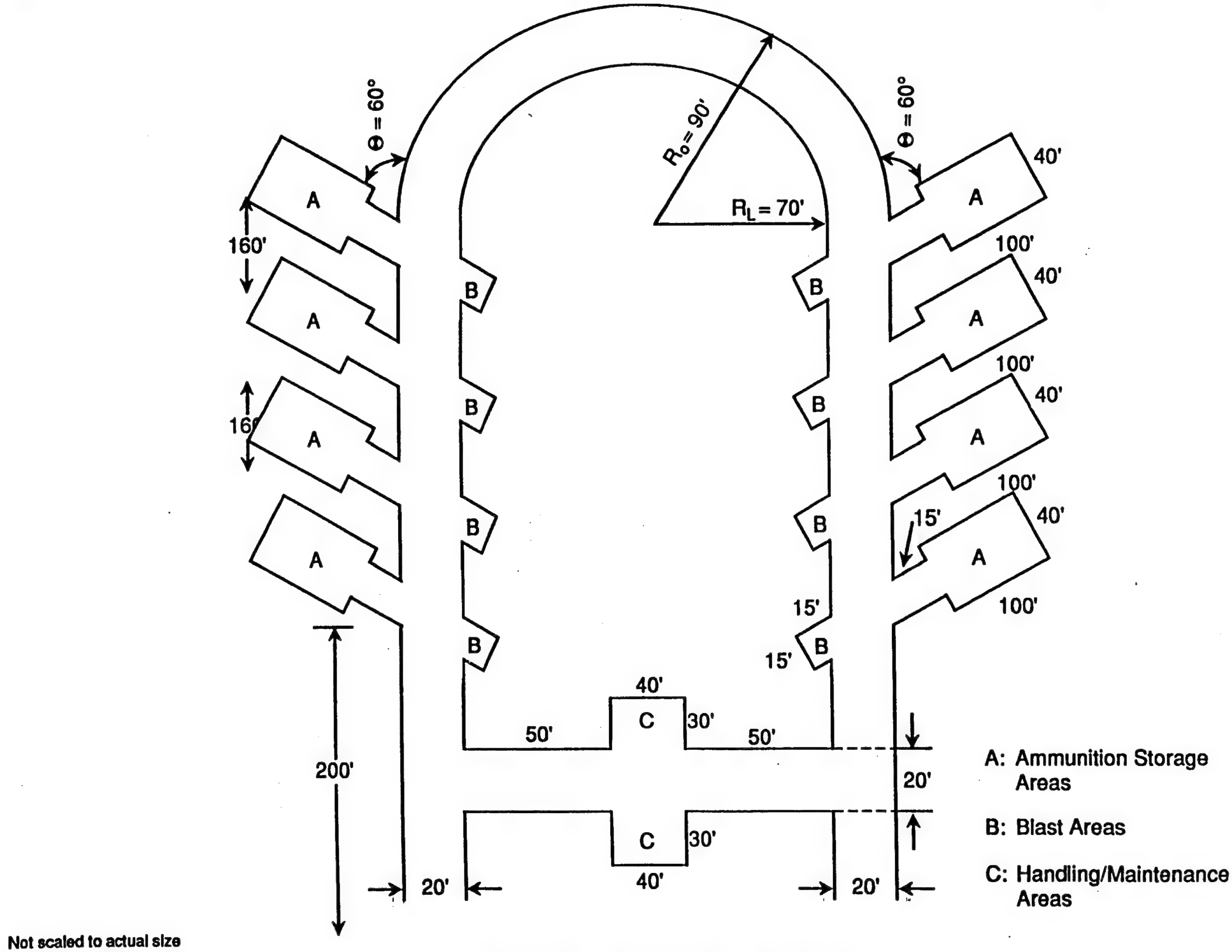
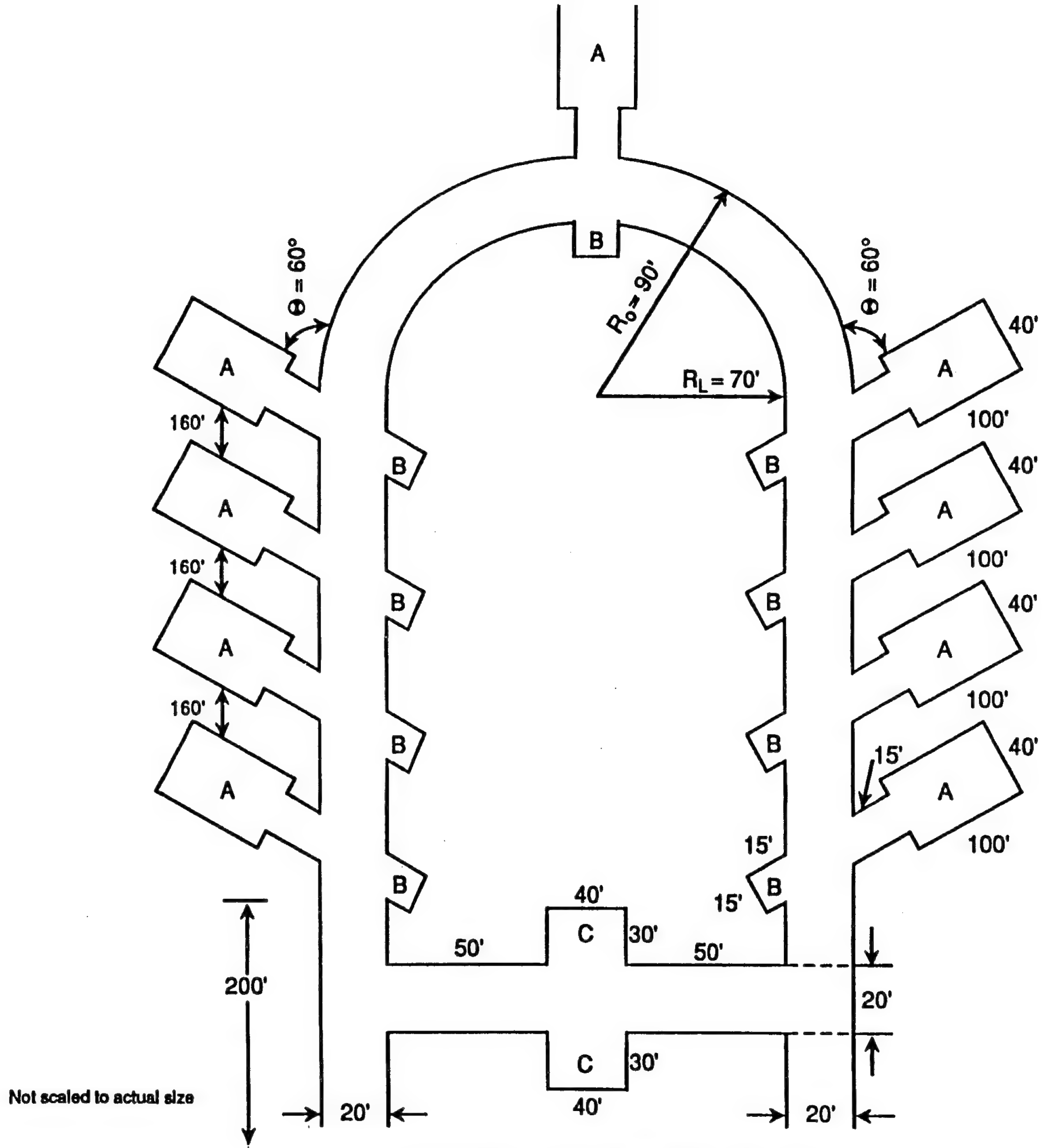


Figure A-10. Alternative III: Fort Knox



A: Ammunition Storage Areas

B: Blast Areas

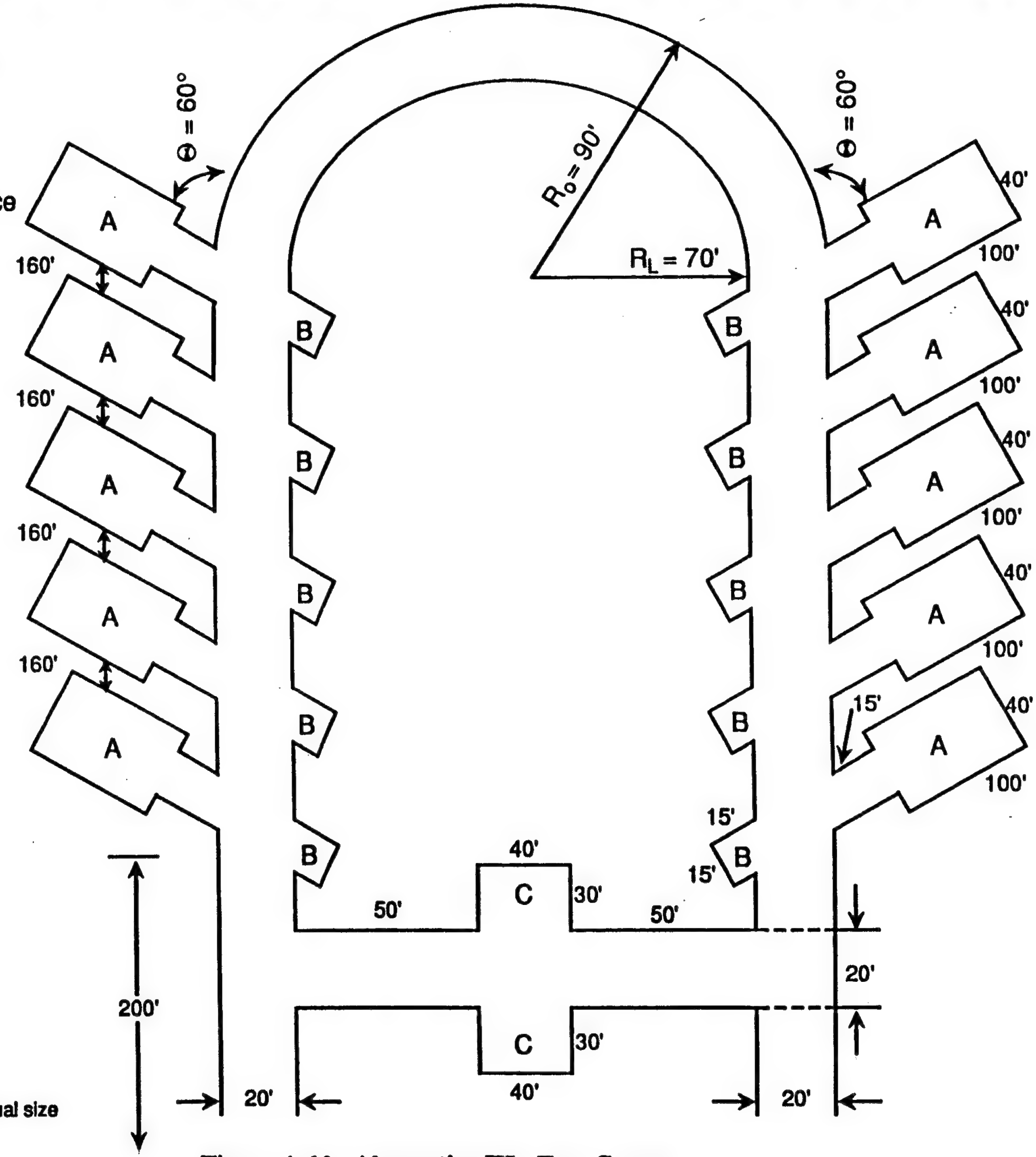
C: Handling/Maintenance Areas

Figure A-11. Alternative III: Fort Drum

A: Ammunition Storage Areas

B: Blast Areas

C: Handling/Maintenance Areas



Not scaled to actual size

Figure A-12. Alternative III: Fort Carson

ANNEX B

LIFE CYCLE COST ANALYSIS

FORT McCOY ABOVEGROUND EXPANSION: ALTERNATIVE I

Real Estate:	Number of Igloos	3	
	Igloo to Igloo Spacing	270	Feet
	Width of Door Area	10	Feet
	Length of Real Estate Needed	1,110	Feet
	Minimum Igloo Spacing	525	Feet
	Buffer Zone	55	Feet
	Width of Real Estate Needed	580	Feet
	Area of Real Estate Needed	14.78	Acres
	Cost of Real Estate Per Acre	$1,000	
	Total Cost of Real Estate	$14,780	
Site Work:	Length of Maintenance Road	650	Feet
	Width of Maintenance Road	20	Feet
	Length of Service Road	1200	Feet
	Width of Service Road	35	Feet
	Depth of Road Surface	12	Inches
	Cost of Surface per Cubic Yard	$45	
	Cost of Building Roadways	$135,000	
	Cost of Clearing Land per Acre	$1,000	
	Cost of Clearing Land	$14,780	
	Cost of Fence per Foot Length	$20	
	Cost of Fencing in New Area	$56,000	
	Cost of Perimeter Lighting	$120,000	
	Total Cost of Site Work:	$325,780	
Cost of Igloos:	Acquisition Cost: Stradleys	$500,000	Per Igloo
	Total Cost of Igloos Built	$1,500,000	

Total Cost of Expanding Above Ground Storage Facilities: $1,840,559

FORT McCOY LIFE CYCLE COST ANALYSIS: ALTERNATIVE I

Labor:	$380,016
Average Hourly Rate:	$13.50
Number of Full-Time Workers :	5
Number of Part-Time Workers :	4
Number of Temporary Workers :	4
Number of Months Temps Present :	5
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$18,000
Design and Construction:	$1,840,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$119,692
EAC of Labor, Equipment, & Maintenance:	$442,016
Equivalent Annual Cost of Alternative I :	$561,708

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$1,840,000
PV of Labor, Equipment, & Maintenance:	$6,794,670
Present Value of Alternative I :	$8,634,670

FORT McCOY LIFE CYCLE COST ANALYSIS: ALTERNATIVE I

Labor:	$380,016
Average Hourly Rate:	$13.50
Number of Full-Time Workers :	5
Number of Part-Time Workers :	4
Number of Temporary Workers :	4
Number of Months Temps Present :	5
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$18,000
Design and Construction:	$1,840,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$195,187
EAC of Labor, Equipment, & Maintenance:	$442,016
Equivalent Annual Cost of Alternative I :	$637,203

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$1,840,000
PV of Labor, Equipment, & Maintenance:	$4,166,885
Present Value of Alternative I :	$6,006,885

FORT McCOY UNDERGROUND STORAGE: ALTERNATIVE II

STORAGE AREAS:

Number of Storage Cells:	2
Length of Storage Area:	100 Feet
Width of Storage Area:	40 Feet
Radius of Circular Arch:	20 Feet
Height of Wall to Beginning of Circular Arch:	4 Feet
Volume of Storage Areas:	5,839 Cubic Yards
Tunnelling Using TBM:	$75 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$175 Per Cubic Yard
Total Cost Using TBM:	$437,955
Total Cost Using Drill & Blast Technique:	$1,021,894
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	20 Cubic Yards/Hour
Drilling Time Using TBM:	11 Work Days
Drilling Time Using Drill & Blast Method:	36 Work Days

ENTRANCE TO STORAGE AREAS:

Length of Entrance:	150 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of Entrances to Storage Areas:	3,523 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$440,388
Total Cost Using Drill & Blast Technique:	$792,699
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	18 Work Days
Drilling Time Using Drill & Blast Method:	44 Work Days

FORT McCOY UNDERGROUND STORAGE: ALTERNATIVE II

Option One:

	Cost	Time (Workdays)
Drill & Blast Storage Areas:	$1,021,894	36
Drill & Blast Entrance Areas:	$792,699	44

Total Cost Expressed in July 1982 Dollars = $1,814,593

Total Cost Expressed in 1993 Dollars = $2,242,237

Total Number of Workdays = 81

Option Two:

	Cost	Time (Workdays)
TBM Storage Areas:	$437,955	11
TBM Entrance Areas:	$440,388	18

Total Cost Expressed in July 1982 Dollars = $878,343

Total Cost Expressed in 1993 Dollars = $1,085,341

Total Number of Workdays = 29

FORT McCOY LIFE CYCLE COST ANALYSIS: ALTERNATIVE II

Labor:	$380,016
Average Hourly Rate:	$13.50
Number of Full-Time Workers :	5
Number of Part-Time Workers :	4
Number of Temporary Workers :	4
Number of Months Temps Present :	5
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$18,000
Design and Construction:	$2,240,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$145,712
EAC of Labor, Equipment, & Maintenance:	$442,016
Equivalent Annual Cost of Alternative II :	**$587,728**

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$2,240,000
PV of Labor, Equipment, & Maintenance:	$6,794,670
Present Value of Alternative II :	**$9,034,670**

FORT McCOY LIFE CYCLE COST ANALYSIS: ALTERNATIVE II

Labor:	$380,016
Average Hourly Rate:	$13.50
Number of Full-Time Workers :	5
Number of Part-Time Workers :	4
Number of Temporary Workers :	4
Number of Months Temps Present :	5
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$18,000
Design and Construction:	$2,240,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$237,619
EAC of Labor, Equipment, & Maintenance:	$442,016
Equivalent Annual Cost of Alternative II :	$679,635

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$2,240,000
PV of Labor, Equipment, & Maintenance:	$4,166,885
Present Value of Alternative II :	$6,406,885

FORT McCOY UNDERGROUND STORAGE: ALTERNATIVE III

STORAGE AREAS:

Number of Storage Cells:	6
Length of Storage Area:	100 Feet
Width of Storage Area:	40 Feet
Radius of Circular Arch:	20 Feet
Height of Wall to Beginning of Circular Arch:	4 Feet
Volume of Storage Areas:	17,518 Cubic Yards
Tunnelling Using TBM:	$75 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$175 Per Cubic Yard
Total Cost Using TBM:	$1,313,864
Total Cost Using Drill & Blast Technique:	$3,065,683
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	20 Cubic Yards/Hour
Drilling Time Using TBM:	34 Work Days
Drilling Time Using Drill & Blast Method:	109 Work Days

ENTRANCE TO STORAGE AREAS:

Length of Entrance:	15 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Angle of Entrance wrt Main Passage:	60 Degrees
Actual Length of Entrance Due to Angle:	26.55 Feet
Volume of Entrances to Storage Areas:	1,871 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$233,820
Total Cost Using Drill & Blast Technique:	$420,876
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	9 Work Days
Drilling Time Using Drill & Blast Method:	23 Work Days

FORT McCOY UNDERGROUND STORAGE: ALTERNATIVE III

BLAST AREAS:

Length of Entrance:	15 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Actual Length of Entrance Due to Angle:	17.32 Feet
Volume of Blast Areas:	1,220 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$152,555
Total Cost Using Drill & Blast Technique	$274,599
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	6 Work Days
Drilling Time Using Drill & Blast Method:	15 Work Days

MAIN PASSAGEWAY:

Outer Radius of Arch:	95 Feet
Inner Radius of Arch:	75 Feet
Path Length (Along Arch):	267.04 Feet
Distance from Entrance to Rib:	100 Feet
Width of Rib Road:	20 Feet
Distance from Rib to First Storage Cell:	80 Feet
Distance Between Storage Cells:	150 Feet
Length of Rib:	150 Feet
Length of Storage Cell Entrance:	23.09 Feet
Total Length of Main Passages:	1648 Feet
Width of Main Passageway:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of Main Passageways:	19,353 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$2,419,164
Total Cost Using Drill & Blast Technique:	$4,354,496
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	97 Work Days
Drilling Time Using Drill & Blast Method:	242 Work Days

FORT McCOY UNDERGROUND STORAGE: ALTERNATIVE III

HANDLING / MAINTENANCE AREAS:

Number of H&M Areas:	2
Length of H&M Area:	40 Feet
Width of H&M Area	30 Feet
Radius of Circular Arch:	15 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of H & M Areas:	1,758 Cubic Yards
Tunnelling Using TBM:	$80 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$200 Per Cubic Yard
Total Cost Using TBM:	$140,665
Total Cost Using Drill & Blast Technique:	$351,662
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	23 Cubic Yards/Hour
Drilling Time Using TBM:	3 Work Days
Drilling Time Using Drill & Blast Method:	10 Work Days

Option A:

	Cost	Time (Workdays)
Drill & Blast Storage Areas:	$3,065,683	109
Drill & Blast Entrance Areas:	$420,876	23
Drill & Blast Blast Areas:	$274,599	15
Drill & Blast H & M Areas:	$351,662	10
TBM Main Passageways:	$2,419,164	97

Total Cost Expressed in July 1982 Dollars = $6,531,984

Total Cost Expressed in 1993 Dollars = $8,071,369

Total Number of Workdays = 254

Option B:

	Cost	Time (Workdays)
TBM Storage Areas:	$1,313,864	34
TBM Entrance Areas:	$233,820	9
Drill & Blast Blast Areas:	$274,599	15
Drill & Blast H & M Areas:	$351,662	10
TBM Main Passageways:	$2,419,164	97

Total Cost Expressed in July 1982 Dollars = $4,593,109

Total Cost Expressed in 1993 Dollars = $5,675,561

Total Number of Workdays = 165

FORT McCOY LIFE CYCLE COST ANALYSIS: ALTERNATIVE III

Labor:	$380,016
Average Hourly Rate:	$13.50
Number of Full-Time Workers :	5
Number of Part-Time Workers :	4
Number of Temporary Workers :	4
Number of Months Temps Present :	5
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$18,000
Design and Construction:	$8,080,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$525,604
EAC of Labor, Equipment, & Maintenance:	$442,016
Equivalent Annual Cost of Alternative III :	$967,620

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$8,080,000
PV of Labor, Equipment, & Maintenance:	$6,794,670
Present Value of Alternative III :	$14,874,670

FORT McCOY LIFE CYCLE COST ANALYSIS: ALTERNATIVE III

Labor:	$380,016
Average Hourly Rate:	$13.50
Number of Full-Time Workers :	5
Number of Part-Time Workers :	4
Number of Temporary Workers :	4
Number of Months Temps Present :	5
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$18,000
Design and Construction:	$8,080,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$857,126
EAC of Labor, Equipment, & Maintenance:	$442,016
Equivalent Annual Cost of Alternative III :	$1,299,142

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$8,080,000
PV of Labor, Equipment, & Maintenance:	$4,166,885
Present Value of Alternative III :	$12,246,885

FORT McCOY ABOVEGROUND EXPANSION: ALTERNATIVE IV

Real Estate:	Number of Igloos	12	
	Igloo to Igloo Spacing	80	Feet
	Width of Door Area	10	Feet
	Length of Real Estate Needed	1,570	Feet
	Minimum Igloo Spacing	540	Feet
	Buffer Zone	100	Feet
	Width of Real Estate Needed	880	Feet
	Area of Real Estate Needed	31.72	Acres
	Cost of Real Estate Per Acre	$1,000	
	Total Cost of Real Estate	$31,717	
Site Work:	Length of Maintenance Road	6,500	Feet
	Width of Maintenance Road	30	Feet
	Depth of Road Surface	12	Inches
	Cost of Surface per Cubic Yard	$45	
	Cost of Building Roadways	$325,000	
	Cost of Fence per Foot Length	$20	
	Cost of Fencing in New Area	$98,000	
	Cost of Perimeter Lighting	$120,000	
	Total Cost of Site Work:	$543,000	
Cost of Igloos:	Acquisition Cost: Stradleys	$310,000	Per Igloo
	Total Cost of Igloos Built	$3,720,000	
Additional Facilities:	Ammo Inspect./Surveill.	$1,900,000	
	Admin. Building	$750,000	

Total Cost of Expanding Above Ground Storage Facilities: $6,944,717

Note: The conceptual cost estimate above compares favorably with the $6.8 million MCA requested at Fort McCoy, WI. for aboveground storage facilities.

FORT McCOY LIFE CYCLE COST ANALYSIS: ALTERNATIVE IV

Labor:	$380,016
Average Hourly Rate:	$13.50
Number of Full-Time Workers :	5
Number of Part-Time Workers :	4
Number of Temporary Workers :	4
Number of Months Temps Present :	5
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$18,000
Design and Construction:	$6,800,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$442,340
EAC of Labor, Equipment, & Maintenance:	$442,016
Equivalent Annual Cost of Alternative IV :	$884,356

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$6,800,000
PV of Labor, Equipment, & Maintenance:	$6,794,670
Present Value of Alternative IV :	$13,594,670

FORT McCOY LIFE CYCLE COST ANALYSIS: ALTERNATIVE IV

Labor:	$380,016
Average Hourly Rate:	$13.50
Number of Full-Time Workers :	5
Number of Part-Time Workers :	4
Number of Temporary Workers :	4
Number of Months Temps Present :	5
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$18,000
Design and Construction:	$6,800,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$721,344
EAC of Labor, Equipment, & Maintenance:	$442,016
Equivalent Annual Cost of Alternative IV :	$1,163,360

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$6,800,000
PV of Labor, Equipment, & Maintenance:	$4,166,885
Present Value of Alternative IV :	$10,966,885

FORT DRUM ABOVEGROUND EXPANSION: ALTERNATIVE I

Real Estate:	Number of Igloos	3	
	Igloo to Igloo Spacing	80	Feet
	Width of Door Area	10	Feet
	Length of Real Estate Needed	1,570	Feet
	Minimum Igloo Spacing	540	Feet
	Buffer Zone	100	Feet
	Width of Real Estate Needed	880	Feet
	Area of Real Estate Needed	31.72	Acres
	Cost of Real Estate Per Acre	$1,000	
	Total Cost of Real Estate	$31,722	
Site Work:	**Total Cost of Site Work:**	$130,000	
Cost of Igloos:	**Total Cost of Igloos Built**	$1,500,000	
Total Cost of Expanding Above Ground Storage Facilities:		$1,661,722	

FORT DRUM LIFE CYCLE COST ANALYSIS: ALTERNATIVE I

Labor:	$626,080
Average Hourly Rate:	$12.00
Number of Full-Time Workers :	15
Number of Part-Time Workers :	0
Number of Temporary Workers :	7
Number of Months Temps Present :	5
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$30,000
Design and Construction:	$1,660,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$107,983
EAC of Labor, Equipment, & Maintenance:	$700,080
Equivalent Annual Cost of Alternative I :	**$808,063**

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$1,660,000
PV of Labor, Equipment, & Maintenance:	$10,761,630
Present Value of Alternative I :	**$12,421,630**

FORT DRUM LIFE CYCLE COST ANALYSIS: ALTERNATIVE I

Labor:	$626,080
Average Hourly Rate:	$12.00
Number of Full-Time Workers :	15
Number of Part-Time Workers :	0
Number of Temporary Workers :	7
Number of Months Temps Present :	5
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$30,000
Design and Construction:	$1,660,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$176,093
EAC of Labor, Equipment, & Maintenance:	$700,080
Equivalent Annual Cost of Alternative I :	$876,173

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$1,660,000
PV of Labor, Equipment, & Maintenance:	$6,599,654
Present Value of Alternative I :	$8,259,654

FORT DRUM UNDERGROUND STORAGE: ALTERNATIVE II

STORAGE AREAS:

Number of Storage Cells:	2
Length of Storage Area:	80 Feet
Width of Storage Area:	40 Feet
Radius of Circular Arch:	20 Feet
Height of Wall to Beginning of Circular Arch:	4 Feet
Volume of Storage Areas:	4,672 Cubic Yards
Tunnelling Using TBM:	$75 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$175 Per Cubic Yard
Total Cost Using TBM:	$350,364
Total Cost Using Drill & Blast Technique:	$817,516
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	20 Cubic Yards/Hour
Drilling Time Using TBM:	9 Work Days
Drilling Time Using Drill & Blast Method:	29 Work Days

ENTRANCE TO STORAGE AREAS:

Length of Entrance:	150 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of Entrances to Storage Areas:	3,523 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$440,388
Total Cost Using Drill & Blast Technique:	$792,699
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	18 Work Days
Drilling Time Using Drill & Blast Method:	44 Work Days

FORT DRUM UNDERGROUND STORAGE: ALTERNATIVE II

Option One:

	Cost	Time (Workdays)
Drill & Blast Storage Areas:	$817,516	29
Drill & Blast Entrance Areas:	$792,699	44

Total Cost Expressed in July 1982 Dollars = $1,610,215

Total Cost Expressed in 1993 Dollars = $1,989,692

Total Number of Workdays = 73

Option Two:

	Cost	Time (Workdays)
TBM Storage Areas:	$350,364	9
TBM Entrance Areas:	$440,388	18

Total Cost Expressed in July 1982 Dollars = $790,752

Total Cost Expressed in 1993 Dollars = $977,108

Total Number of Workdays = 27

FORT DRUM LIFE CYCLE COST ANALYSIS: ALTERNATIVE II

Labor:	$626,080
Average Hourly Rate:	$12.00
Number of Full-Time Workers :	15
Number of Part-Time Workers :	0
Number of Temporary Workers :	7
Number of Months Temps Present :	5
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$30,000
Design and Construction:	$1,990,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$129,450
EAC of Labor, Equipment, & Maintenance:	$700,080
Equivalent Annual Cost of Alternative II :	$829,530

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$1,990,000
PV of Labor, Equipment, & Maintenance:	$10,761,630
Present Value of Alternative II :	$12,751,630

FORT DRUM LIFE CYCLE COST ANALYSIS: ALTERNATIVE II

Labor:	$626,080
Average Hourly Rate:	$12.00
Number of Full-Time Workers :	15
Number of Part-Time Workers :	0
Number of Temporary Workers :	7
Number of Months Temps Present :	5
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$30,000
Design and Construction:	$1,990,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$211,099
EAC of Labor, Equipment, & Maintenance:	$700,080
Equivalent Annual Cost of Alternative II :	$911,179

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$1,990,000
PV of Labor, Equipment, & Maintenance:	$6,599,654
Present Value of Alternative II :	$8,589,654

FORT DRUM UNDERGROUND STORAGE: ALTERNATIVE III

STORAGE AREAS:

Number of Storage Cells:	9
Length of Storage Area:	165 Feet
Width of Storage Area:	40 Feet
Radius of Circular Arch:	20 Feet
Height of Wall to Beginning of Circular Arch:	4 Feet
Volume of Storage Areas:	43,358 Cubic Yards
Tunnelling Using TBM:	$75 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$175 Per Cubic Yard
Total Cost Using TBM:	$3,251,814
Total Cost Using Drill & Blast Technique:	$7,587,566
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	20 Cubic Yards/Hour
Drilling Time Using TBM:	83 Work Days
Drilling Time Using Drill & Blast Method:	271 Work Days

ENTRANCE TO STORAGE AREAS:

Length of Entrance:	15 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Angle of Entrance wrt Main Passage:	60 Degrees
Actual Length of Entrance Due to Angle:	26.55 Feet
Volume of Entrances to Storage Areas:	2,806 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$350,730
Total Cost Using Drill & Blast Technique:	$631,314
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	14 Work Days
Drilling Time Using Drill & Blast Method:	35 Work Days

FORT DRUM UNDERGROUND STORAGE: ALTERNATIVE III

BLAST AREAS:

Length of Entrance:	15 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Actual Length of Entrance Due to Angle:	17.32 Feet
Volume of Blast Areas:	1,831 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$228,833
Total Cost Using Drill & Blast Technique	$411,899
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	9 Work Days
Drilling Time Using Drill & Blast Method:	23 Work Days

MAIN PASSAGEWAY:

Outer Radius of Arch:	95 Feet
Inner Radius of Arch:	75 Feet
Path Length (Along Arch):	267.04 Feet
Distance from Entrance to Rib:	100 Feet
Width of Rib Road:	20 Feet
Distance from Rib to First Storage Cell:	80 Feet
Distance Between Storage Cells:	150 Feet
Length of Rib:	150 Feet
Length of Storage Cell Entrance:	23.09 Feet
Total Length of Main Passages:	1994 Feet
Width of Main Passageway:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of Main Passageways:	23,419 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$2,927,355
Total Cost Using Drill & Blast Technique:	$5,269,239
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	117 Work Days
Drilling Time Using Drill & Blast Method:	293 Work Days

FORT DRUM UNDERGROUND STORAGE: ALTERNATIVE III

HANDLING / MAINTENANCE AREAS:

Number of H&M Areas:	2
Length of H&M Area:	40 Feet
Width of H&M Area	30 Feet
Radius of Circular Arch:	15 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of H & M Areas:	1,758 Cubic Yards
Tunnelling Using TBM:	$80 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$200 Per Cubic Yard
Total Cost Using TBM:	$140,665
Total Cost Using Drill & Blast Technique:	$351,662
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	23 Cubic Yards/Hour
Drilling Time Using TBM:	3 Work Days
Drilling Time Using Drill & Blast Method:	10 Work Days

Option A:

	Cost	Time (Workdays)
Drill & Blast Storage Areas:	$7,587,566	271
Drill & Blast Entrance Areas:	$631,314	35
Drill & Blast Blast Areas:	$411,899	23
Drill & Blast H & M Areas:	$351,662	10
TBM Main Passageways:	$2,927,355	117

Total Cost Expressed in July 1982 Dollars = $11,909,794

Total Cost Expressed in 1993 Dollars = $14,716,561

Total Number of Workdays = 456

Option B:

	Cost	Time (Workdays)
TBM Storage Areas:	$3,251,814	83
TBM Entrance Areas:	$350,730	14
Drill & Blast Blast Areas:	$411,899	23
Drill & Blast H & M Areas:	$351,662	10
TBM Main Passageways:	$2,927,355	117

Total Cost Expressed in July 1982 Dollars = $7,293,459

Total Cost Expressed in 1993 Dollars = $9,012,299

Total Number of Workdays = 247

FORT DRUM LIFE CYCLE COST ANALYSIS: ALTERNATIVE III

Labor:	$626,080
Average Hourly Rate:	$12.00
Number of Full-Time Workers :	15
Number of Part-Time Workers :	0
Number of Temporary Workers :	7
Number of Months Temps Present :	5
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$30,000
Design and Construction:	$14,700,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$956,235
EAC of Labor, Equipment, & Maintenance:	$700,080
Equivalent Annual Cost of Alternative III :	$1,656,315

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$14,700,000
PV of Labor, Equipment, & Maintenance:	$10,761,630
Present Value of Alternative III :	$25,461,630

FORT DRUM LIFE CYCLE COST ANALYSIS: ALTERNATIVE III

Labor:	$626,080
Average Hourly Rate:	$12.00
Number of Full-Time Workers :	15
Number of Part-Time Workers :	0
Number of Temporary Workers :	7
Number of Months Temps Present :	5
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$30,000
Design and Construction:	$14,700,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$1,559,376
EAC of Labor, Equipment, & Maintenance:	$700,080

Equivalent Annual Cost of Alternative III : $2,259,456

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$14,700,000
PV of Labor, Equipment, & Maintenance:	$6,599,654

Present Value of Alternative III : $21,299,654

FORT DIX LIFE CYCLE COST ANALYSIS: ALTERNATIVE IV

Labor:	$393,120
Average Hourly Rate:	$13.50
Number of Full-Time Workers :	10
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$35,000
Maintenance:	$20,000
Design and Construction:	$11,000,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$715,550
EAC of Labor, Equipment, & Maintenance:	$448,120
Equivalent Annual Cost of Alternative IV :	$1,163,670

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$11,000,000
PV of Labor, Equipment, & Maintenance:	$6,888,501
Present Value of Alternative IV :	$17,888,501

FORT DIX LIFE CYCLE COST ANALYSIS: ALTERNATIVE IV

Labor:	$393,120
Average Hourly Rate:	$13.50
Number of Full-Time Workers :	10
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$35,000
Maintenance:	$20,000
Design and Construction:	$11,000,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$1,166,880
EAC of Labor, Equipment, & Maintenance:	$448,120
Equivalent Annual Cost of Alternative IV :	$1,615,000

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$11,000,000
PV of Labor, Equipment, & Maintenance:	$4,224,427
Present Value of Alternative IV :	$15,224,427

FORT KNOX LIFE CYCLE COST ANALYSIS: ALTERNATIVE I

Labor:	$541,632
Average Hourly Rate:	$12.00
Number of Full-Time Workers :	14
Number of Part-Time Workers :	2
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$40,000
Design and Construction:	$500,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$32,525
EAC of Labor, Equipment, & Maintenance:	$625,632
Equivalent Annual Cost of Alternative I :	**$658,157**

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$500,000
PV of Labor, Equipment, & Maintenance:	$9,617,215
Present Value of Alternative I :	**$10,117,215**

FORT KNOX LIFE CYCLE COST ANALYSIS: ALTERNATIVE I

Labor:	$541,632
Average Hourly Rate:	$12.00
Number of Full-Time Workers :	14
Number of Part-Time Workers :	2
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$40,000
Design and Construction:	$500,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$53,040
EAC of Labor, Equipment, & Maintenance:	$625,632

Equivalent Annual Cost of Alternative I : $678,672

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$500,000
PV of Labor, Equipment, & Maintenance:	$5,897,833

Present Value of Alternative I : $6,397,833

FORT KNOX UNDERGROUND STORAGE: ALTERNATIVE II

STORAGE AREAS:

Number of Storage Cells:	2
Length of Storage Area:	80 Feet
Width of Storage Area:	40 Feet
Radius of Circular Arch:	20 Feet
Height of Wall to Beginning of Circular Arch:	4 Feet
Volume of Storage Areas:	4,672 Cubic Yards
Tunnelling Using TBM:	$75 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$175 Per Cubic Yard
Total Cost Using TBM:	$350,364
Total Cost Using Drill & Blast Technique:	$817,516
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	20 Cubic Yards/Hour
Drilling Time Using TBM:	9 Work Days
Drilling Time Using Drill & Blast Method:	29 Work Days

ENTRANCE TO STORAGE AREAS:

Length of Entrance:	150 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of Entrances to Storage Areas:	3,523 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$440,388
Total Cost Using Drill & Blast Technique:	$792,699
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	18 Work Days
Drilling Time Using Drill & Blast Method:	44 Work Days

FORT KNOX UNDERGROUND STORAGE: ALTERNATIVE II

Option One:

	Cost	Time (Workdays)
Drill & Blast Storage Areas:	$817,516	29
Drill & Blast Entrance Areas:	$792,699	44

Total Cost Expressed in July 1982 Dollars = $1,610,215

Total Cost Expressed in 1993 Dollars = $1,989,692

Total Number of Workdays = 73

Option Two:

	Cost	Time (Workdays)
TBM Storage Areas:	$350,364	9
TBM Entrance Areas:	$440,388	18

Total Cost Expressed in July 1982 Dollars = $790,752

Total Cost Expressed in 1993 Dollars = $977,108

Total Number of Workdays = 27

FORT KNOX LIFE CYCLE COST ANALYSIS: ALTERNATIVE II

Labor:	$541,632
Average Hourly Rate:	$12.00
Number of Full-Time Workers :	14
Number of Part-Time Workers :	2
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$40,000
Design and Construction:	$1,990,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$129,450
EAC of Labor, Equipment, & Maintenance:	$625,632
Equivalent Annual Cost of Alternative II :	$755,082

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$1,990,000
PV of Labor, Equipment, & Maintenance:	$9,617,215
Present Value of Alternative II :	$11,607,215

FORT KNOX LIFE CYCLE COST ANALYSIS: ALTERNATIVE II

Labor:	$541,632
Average Hourly Rate:	$12.00
Number of Full-Time Workers :	14
Number of Part-Time Workers :	2
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$40,000
Design and Construction:	$1,990,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$211,099
EAC of Labor, Equipment, & Maintenance:	$625,632
Equivalent Annual Cost of Alternative II :	$836,731

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$1,990,000
PV of Labor, Equipment, & Maintenance:	$5,897,833
Present Value of Alternative II :	$7,887,833

FORT KNOX UNDERGROUND STORAGE: ALTERNATIVE III

STORAGE AREAS:

Number of Storage Cells:	8
Length of Storage Area:	165 Feet
Width of Storage Area:	40 Feet
Radius of Circular Arch:	20 Feet
Height of Wall to Beginning of Circular Arch:	4 Feet
Volume of Storage Areas:	38,540 Cubic Yards
Tunnelling Using TBM:	$75 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$175 Per Cubic Yard
Total Cost Using TBM:	$2,890,501
Total Cost Using Drill & Blast Technique:	$6,744,503
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	20 Cubic Yards/Hour
Drilling Time Using TBM:	74 Work Days
Drilling Time Using Drill & Blast Method:	241 Work Days

ENTRANCE TO STORAGE AREAS:

Length of Entrance:	15 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Angle of Entrance wrt Main Passage:	60 Degrees
Actual Length of Entrance Due to Angle:	26.55 Feet
Volume of Entrances to Storage Areas:	2,494 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$311,760
Total Cost Using Drill & Blast Technique:	$561,168
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	12 Work Days
Drilling Time Using Drill & Blast Method:	31 Work Days

FORT KNOX UNDERGROUND STORAGE: ALTERNATIVE III

BLAST AREAS:

Length of Entrance:	15 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Actual Length of Entrance Due to Angle:	17.32 Feet
Volume of Blast Areas:	1,627 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$203,407
Total Cost Using Drill & Blast Technique	$366,132
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	8 Work Days
Drilling Time Using Drill & Blast Method:	20 Work Days

MAIN PASSAGEWAY:

Outer Radius of Arch:	95 Feet
Inner Radius of Arch:	75 Feet
Path Length (Along Arch):	267.04 Feet
Distance from Entrance to Rib:	100 Feet
Width of Rib Road:	20 Feet
Distance from Rib to First Storage Cell:	80 Feet
Distance Between Storage Cells:	150 Feet
Length of Rib:	150 Feet
Length of Storage Cell Entrance:	23.09 Feet
Total Length of Main Passages:	1994 Feet
Width of Main Passageway:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of Main Passageways:	23,419 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$2,927,355
Total Cost Using Drill & Blast Technique:	$5,269,239
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	117 Work Days
Drilling Time Using Drill & Blast Method:	293 Work Days

FORT KNOX UNDERGROUND STORAGE: ALTERNATIVE III

HANDLING / MAINTENANCE AREAS:

Number of H&M Areas:	2
Length of H&M Area:	40 Feet
Width of H&M Area	30 Feet
Radius of Circular Arch:	15 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of H & M Areas:	1,758 Cubic Yards
Tunnelling Using TBM:	$80 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$200 Per Cubic Yard
Total Cost Using TBM:	$140,665
Total Cost Using Drill & Blast Technique:	$351,662
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	23 Cubic Yards/Hour
Drilling Time Using TBM:	3 Work Days
Drilling Time Using Drill & Blast Method:	10 Work Days

Option A:

	Cost	Time (Workdays)
Drill & Blast Storage Areas:	$6,744,503	241
Drill & Blast Entrance Areas:	$561,168	31
Drill & Blast Blast Areas:	$366,132	20
Drill & Blast H & M Areas:	$351,662	10
TBM Main Passageways:	$2,927,355	117

Total Cost Expressed in July 1982 Dollars = $10,950,819

Total Cost Expressed in 1993 Dollars = $13,531,585

Total Number of Workdays = 419

Option B:

	Cost	Time (Workdays)
TBM Storage Areas:	$2,890,501	74
TBM Entrance Areas:	$311,760	12
Drill & Blast Blast Areas:	$366,132	20
Drill & Blast H & M Areas:	$351,662	10
TBM Main Passageways:	$2,927,355	117

Total Cost Expressed in July 1982 Dollars = $6,847,410

Total Cost Expressed in 1993 Dollars = $8,461,130

Total Number of Workdays = 234

FORT KNOX LIFE CYCLE COST ANALYSIS: ALTERNATIVE III

Labor:	$541,632
Average Hourly Rate:	$12.00
Number of Full-Time Workers :	14
Number of Part-Time Workers :	2
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$40,000
Design and Construction:	$13,530,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$880,127
EAC of Labor, Equipment, & Maintenance:	$625,632
Equivalent Annual Cost of Alternative III :	**$1,505,759**

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$13,530,000
PV of Labor, Equipment, & Maintenance:	$9,617,215
Present Value of Alternative III :	**$23,147,215**

FORT KNOX LIFE CYCLE COST ANALYSIS: ALTERNATIVE III

Labor:	$541,632
Average Hourly Rate:	$12.00
Number of Full-Time Workers :	14
Number of Part-Time Workers :	2
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$40,000
Design and Construction:	$13,530,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$1,435,262
EAC of Labor, Equipment, & Maintenance:	$625,632
Equivalent Annual Cost of Alternative III :	$2,060,894

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$13,530,000
PV of Labor, Equipment, & Maintenance:	$5,897,833
Present Value of Alternative III :	$19,427,833

FORT HUACHUCA UNDERGROUND STORAGE: ALTERNATIVE II

STORAGE AREAS:

Number of Storage Cells:	2
Length of Storage Area:	100 Feet
Width of Storage Area:	40 Feet
Radius of Circular Arch:	20 Feet
Height of Wall to Beginning of Circular Arch:	4 Feet
Volume of Storage Areas:	5,839 Cubic Yards
Tunnelling Using TBM:	$75 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$175 Per Cubic Yard
Total Cost Using TBM:	$437,955
Total Cost Using Drill & Blast Technique:	$1,021,894
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	20 Cubic Yards/Hour
Drilling Time Using TBM:	11 Work Days
Drilling Time Using Drill & Blast Method:	36 Work Days

ENTRANCE TO STORAGE AREAS:

Length of Entrance:	150 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of Entrances to Storage Areas:	3,523 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$440,388
Total Cost Using Drill & Blast Technique:	$792,699
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	18 Work Days
Drilling Time Using Drill & Blast Method:	44 Work Days

FORT HUACHUCA UNDERGROUND STORAGE: ALTERNATIVE II

Option One:

	Cost	Time (Workdays)
Drill & Blast Storage Areas:	$1,021,894	36
Drill & Blast Entrance Areas:	$792,699	44

Total Cost Expressed in July 1982 Dollars = $1,814,593

Total Cost Expressed in 1993 Dollars = $2,242,237

Total Number of Workdays = 81

Option Two:

	Cost	Time (Workdays)
TBM Storage Areas:	$437,955	11
TBM Entrance Areas:	$440,388	18

Total Cost Expressed in July 1982 Dollars = $878,343

Total Cost Expressed in 1993 Dollars = $1,085,341

Total Number of Workdays = 29

FORT HUACHUCA LIFE CYCLE COST ANALYSIS: ALTERNATIVE II

Labor:	$174,720
Average Hourly Rate:	$15.00
Number of Full-Time Workers :	4
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$25,000
Maintenance:	$20,000
Design and Construction:	$2,240,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$145,712
EAC of Labor, Equipment, & Maintenance:	$219,720
Equivalent Annual Cost of Alternative II :	$365,432

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$2,240,000
PV of Labor, Equipment, & Maintenance:	$3,377,536
Present Value of Alternative II :	$5,617,536

FORT HUACHUCA LIFE CYCLE COST ANALYSIS: ALTERNATIVE II

Labor:	$174,720
Average Hourly Rate:	$15.00
Number of Full-Time Workers :	4
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$25,000
Maintenance:	$20,000
Design and Construction:	$2,240,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$237,619
EAC of Labor, Equipment, & Maintenance:	$219,720
Equivalent Annual Cost of Alternative II :	$457,339

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$2,240,000
PV of Labor, Equipment, & Maintenance:	$2,071,300
Present Value of Alternative II :	$4,311,300

FORT HUACHUCA UNDERGROUND STORAGE: ALTERNATIVE III

STORAGE AREAS:

Number of Storage Cells:	6
Length of Storage Area:	100 Feet
Width of Storage Area:	40 Feet
Radius of Circular Arch:	20 Feet
Height of Wall to Beginning of Circular Arch:	4 Feet
Volume of Storage Areas:	17,518 Cubic Yards
Tunnelling Using TBM:	$75 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$175 Per Cubic Yard
Total Cost Using TBM:	$1,313,864
Total Cost Using Drill & Blast Technique:	$3,065,683
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	20 Cubic Yards/Hour
Drilling Time Using TBM:	34 Work Days
Drilling Time Using Drill & Blast Method:	109 Work Days

ENTRANCE TO STORAGE AREAS:

Length of Entrance:	15 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Angle of Entrance wrt Main Passage:	60 Degrees
Actual Length of Entrance Due to Angle:	26.55 Feet
Volume of Entrances to Storage Areas:	1,871 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$233,820
Total Cost Using Drill & Blast Technique:	$420,876
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	9 Work Days
Drilling Time Using Drill & Blast Method:	23 Work Days

FORT HUACHUCA UNDERGROUND STORAGE: ALTERNATIVE III

BLAST AREAS:

Length of Entrance:	15 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Actual Length of Entrance Due to Angle:	17.32 Feet
Volume of Blast Areas:	1,220 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$152,555
Total Cost Using Drill & Blast Technique	$274,599
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	6 Work Days
Drilling Time Using Drill & Blast Method:	15 Work Days

MAIN PASSAGEWAY:

Outer Radius of Arch:	95 Feet
Inner Radius of Arch:	75 Feet
Path Length (Along Arch):	267.04 Feet
Distance from Entrance to Rib:	100 Feet
Width of Rib Road:	20 Feet
Distance from Rib to First Storage Cell:	80 Feet
Distance Between Storage Cells:	150 Feet
Length of Rib:	150 Feet
Length of Storage Cell Entrance:	23.09 Feet
Total Length of Main Passages:	1648 Feet
Width of Main Passageway:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of Main Passageways:	19,353 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$2,419,164
Total Cost Using Drill & Blast Technique:	$4,354,496
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	97 Work Days
Drilling Time Using Drill & Blast Method:	242 Work Days

FORT HUACHUCA UNDERGROUND STORAGE: ALTERNATIVE III

HANDLING / MAINTENANCE AREAS:

Number of H&M Areas:	2
Length of H&M Area:	40 Feet
Width of H&M Area	30 Feet
Radius of Circular Arch:	15 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of H & M Areas:	1,758 Cubic Yards
Tunnelling Using TBM:	$80 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$200 Per Cubic Yard
Total Cost Using TBM:	$140,665
Total Cost Using Drill & Blast Technique:	$351,662
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	23 Cubic Yards/Hour
Drilling Time Using TBM:	3 Work Days
Drilling Time Using Drill & Blast Method:	10 Work Days

Option A:

	Cost	Time (Workdays)
Drill & Blast Storage Areas:	$3,065,683	109
Drill & Blast Entrance Areas:	$420,876	23
Drill & Blast Blast Areas:	$274,599	15
Drill & Blast H & M Areas:	$351,662	10
TBM Main Passageways:	$2,419,164	97

Total Cost Expressed in July 1982 Dollars = $6,531,984

Total Cost Expressed in 1993 Dollars = $8,071,369

Total Number of Workdays = 254

Option B:

	Cost	Time (Workdays)
TBM Storage Areas:	$1,313,864	34
TBM Entrance Areas:	$233,820	9
Drill & Blast Blast Areas:	$274,599	15
Drill & Blast H & M Areas:	$351,662	10
TBM Main Passageways:	$2,419,164	97

Total Cost Expressed in July 1982 Dollars = $4,593,109

Total Cost Expressed in 1993 Dollars = $5,675,561

Total Number of Workdays = 165

FORT HUACHUCA LIFE CYCLE COST ANALYSIS: ALTERNATIVE III

Labor:	$174,720
Average Hourly Rate:	$15.00
Number of Full-Time Workers :	4
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$25,000
Maintenance:	$20,000
Design and Construction:	$8,070,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$524,954
EAC of Labor, Equipment, & Maintenance:	$219,720
Equivalent Annual Cost of Alternative III :	$744,674

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$8,070,000
PV of Labor, Equipment, & Maintenance:	$3,377,536
Present Value of Alternative III :	$11,447,536

FORT HUACHUCA LIFE CYCLE COST ANALYSIS: ALTERNATIVE III

Labor:	$174,720
Average Hourly Rate:	$15.00
Number of Full-Time Workers :	4
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$25,000
Maintenance:	$20,000
Design and Construction:	$8,070,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$856,066
EAC of Labor, Equipment, & Maintenance:	$219,720
Equivalent Annual Cost of Alternative III :	**$1,075,786**

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$8,070,000
PV of Labor, Equipment, & Maintenance:	$2,071,300
Present Value of Alternative III :	**$10,141,300**

FORT HUACHUCA ABOVEGROUND EXPANSION: ALTERNATIVE IV

Real Estate:	Number of Igloos	12
	Igloo to Igloo Spacing	80 Feet
	Width of Door Area	10 Feet
	Length of Real Estate Needed	1,570 Feet
	Minimum Igloo Spacing	540 Feet
	Buffer Zone	100 Feet
	Width of Real Estate Needed	880 Feet
	Area of Real Estate Needed	31.72 Acres
	Cost of Real Estate Per Acre	$1,000
	Total Cost of Real Estate	$31,717
Site Work:	Length of Maintenance Road	6,500 Feet
	Width of Maintenance Road	30 Feet
	Depth of Road Surface	12 Inches
	Cost of Surface per Cubic Yard	$45
	Cost of Building Roadways	$325,000
	Cost of Fence per Foot Length	$20
	Cost of Fencing in New Area	$98,000
	Cost of Perimeter Lighting	$120,000
	Total Cost of Site Work:	$543,000
Cost of Igloos:	Acquisition Cost: Stradleys	$310,000 Per Igloo
	Total Cost of Igloos Built	$3,720,000
Additional Facilities:	Ammo Inspect./Surveill.	$1,900,000
	Admin. Building	$750,000

Total Cost of Expanding Above Ground Storage Facilities: $6,944,717

Note: The conceptual cost estimate above compares favorably with the $6.8 million MCA requested at Fort McCoy, WI. for the same aboveground storage facilities.

FORT HUACHUCA LIFE CYCLE COST ANALYSIS: ALTERNATIVE IV

Labor:	$174,720
Average Hourly Rate:	$15.00
Number of Full-Time Workers :	4
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$25,000
Maintenance:	$20,000
Design and Construction:	$6,800,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$442,340
EAC of Labor, Equipment, & Maintenance:	$219,720
Equivalent Annual Cost of Alternative IV :	$662,060

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$6,800,000
PV of Labor, Equipment, & Maintenance:	$3,377,536
Present Value of Alternative IV :	$10,177,536

FORT HUACHUCA LIFE CYCLE COST ANALYSIS: ALTERNATIVE IV

Labor:	$174,720
Average Hourly Rate:	$15.00
Number of Full-Time Workers :	4
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$25,000
Maintenance:	$20,000
Design and Construction:	$6,800,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$721,344
EAC of Labor, Equipment, & Maintenance:	$219,720
Equivalent Annual Cost of Alternative IV :	$941,064

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$6,800,000
PV of Labor, Equipment, & Maintenance:	$2,071,300
Present Value of Alternative IV :	$8,871,300

FORT CARSON LIFE CYCLE COST ANALYSIS: ALTERNATIVE I

Labor:	$436,800
Average Hourly Rate:	$15.00
Number of Full-Time Workers :	10
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$20,000
Design and Construction:	$1,000,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$65,050
EAC of Labor, Equipment, & Maintenance:	$500,800
Equivalent Annual Cost of Alternative I :	$565,850

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$1,000,000
PV of Labor, Equipment, & Maintenance:	$7,698,298
Present Value of Alternative I :	$8,698,298

FORT CARSON LIFE CYCLE COST ANALYSIS: ALTERNATIVE I

Labor:	$436,800
Average Hourly Rate:	$15.00
Number of Full-Time Workers :	10
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$20,000
Design and Construction:	$1,000,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$106,080
EAC of Labor, Equipment, & Maintenance:	$500,800
Equivalent Annual Cost of Alternative I :	$606,880

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$1,000,000
PV of Labor, Equipment, & Maintenance:	$4,721,042
Present Value of Alternative I :	$5,721,042

FORT CARSON UNDERGROUND STORAGE: ALTERNATIVE II

STORAGE AREAS:

Number of Storage Cells:	2	
Length of Storage Area:	80	Feet
Width of Storage Area:	40	Feet
Radius of Circular Arch:	20	Feet
Height of Wall to Beginning of Circular Arch:	4	Feet
Volume of Storage Areas:	4,672	Cubic Yards
Tunnelling Using TBM:	$75	Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$175	Per Cubic Yard
Total Cost Using TBM:	$350,364	
Total Cost Using Drill & Blast Technique:	$817,516	
Tunnelling Rate Using TBM:	65	Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	20	Cubic Yards/Hour
Drilling Time Using TBM:	9	Work Days
Drilling Time Using Drill & Blast Method:	29	Work Days

ENTRANCE TO STORAGE AREAS:

Length of Entrance:	150	Feet
Width of Entrance:	20	Feet
Radius of Circular Arch:	10	Feet
Height of Wall to Beginning of Circular Arch:	8	Feet
Volume of Entrances to Storage Areas:	3,523	Cubic Yards
Tunnelling Using TBM:	$125	Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225	Per Cubic Yard
Total Cost Using TBM:	$440,388	
Total Cost Using Drill & Blast Technique:	$792,699	
Tunnelling Rate Using TBM:	25	Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10	Cubic Yards/Hour
Drilling Time Using TBM:	18	Work Days
Drilling Time Using Drill & Blast Method:	44	Work Days

FORT CARSON UNDERGROUND STORAGE: ALTERNATIVE II

Option One:

	Cost	Time (Workdays)
Drill & Blast Storage Areas:	$817,516	29
Drill & Blast Entrance Areas:	$792,699	44

Total Cost Expressed in July 1982 Dollars = $1,610,215

Total Cost Expressed in 1993 Dollars = $1,989,692

Total Number of Workdays = 73

Option Two:

	Cost	Time (Workdays)
TBM Storage Areas:	$350,364	9
TBM Entrance Areas:	$440,388	18

Total Cost Expressed in July 1982 Dollars = $790,752

Total Cost Expressed in 1993 Dollars = $977,108

Total Number of Workdays = 27

FORT CARSON LIFE CYCLE COST ANALYSIS: ALTERNATIVE II

Labor:	$436,800
Average Hourly Rate:	$15.00
Number of Full-Time Workers :	10
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$20,000
Design and Construction:	$1,990,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$129,450
EAC of Labor, Equipment, & Maintenance:	$500,800
Equivalent Annual Cost of Alternative II :	$630,250

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$1,990,000
PV of Labor, Equipment, & Maintenance:	$7,698,298
Present Value of Alternative II :	$9,688,298

FORT CARSON LIFE CYCLE COST ANALYSIS: ALTERNATIVE II

Labor:	$436,800
Average Hourly Rate:	$15.00
Number of Full-Time Workers :	10
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$20,000
Design and Construction:	$1,990,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$211,099
EAC of Labor, Equipment, & Maintenance:	$500,800
Equivalent Annual Cost of Alternative II :	**$711,899**

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$1,990,000
PV of Labor, Equipment, & Maintenance:	$4,721,042
Present Value of Alternative II :	**$6,711,042**

FORT CARSON UNDERGROUND STORAGE: ALTERNATIVE III

STORAGE AREAS:

Number of Storage Cells:	10
Length of Storage Area:	165 Feet
Width of Storage Area:	40 Feet
Radius of Circular Arch:	20 Feet
Height of Wall to Beginning of Circular Arch:	4 Feet
Volume of Storage Areas:	48,175 Cubic Yards
Tunnelling Using TBM:	$75 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$175 Per Cubic Yard
Total Cost Using TBM:	$3,613,127
Total Cost Using Drill & Blast Technique:	$8,430,629
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	20 Cubic Yards/Hour
Drilling Time Using TBM:	93 Work Days
Drilling Time Using Drill & Blast Method:	301 Work Days

ENTRANCE TO STORAGE AREAS:

Length of Entrance:	15 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Angle of Entrance wrt Main Passage:	60 Degrees
Actual Length of Entrance Due to Angle:	26.55 Feet
Volume of Entrances to Storage Areas:	3,118 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$389,700
Total Cost Using Drill & Blast Technique:	$701,460
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	16 Work Days
Drilling Time Using Drill & Blast Method:	39 Work Days

FORT CARSON UNDERGROUND STORAGE: ALTERNATIVE III

BLAST AREAS:

Length of Entrance:	15 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Actual Length of Entrance Due to Angle:	17.32 Feet
Volume of Blast Areas:	2,034 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$254,258
Total Cost Using Drill & Blast Technique	$457,665
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	10 Work Days
Drilling Time Using Drill & Blast Method:	25 Work Days

MAIN PASSAGEWAY:

Outer Radius of Arch:	95 Feet
Inner Radius of Arch:	75 Feet
Path Length (Along Arch):	267.04 Feet
Distance from Entrance to Rib:	100 Feet
Width of Rib Road:	20 Feet
Distance from Rib to First Storage Cell:	80 Feet
Distance Between Storage Cells:	150 Feet
Length of Rib:	150 Feet
Length of Storage Cell Entrance:	23.09 Feet
Total Length of Main Passages:	2340 Feet
Width of Main Passageway:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of Main Passageways:	27,484 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$3,435,545
Total Cost Using Drill & Blast Technique:	$6,183,982
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	137 Work Days
Drilling Time Using Drill & Blast Method:	344 Work Days

FORT CARSON UNDERGROUND STORAGE: ALTERNATIVE III

HANDLING / MAINTENANCE AREAS:

Number of H&M Areas:	2
Length of H&M Area:	40 Feet
Width of H&M Area	30 Feet
Radius of Circular Arch:	15 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of H & M Areas:	1,758 Cubic Yards
Tunnelling Using TBM:	$80 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$200 Per Cubic Yard
Total Cost Using TBM:	$140,665
Total Cost Using Drill & Blast Technique:	$351,662
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	23 Cubic Yards/Hour
Drilling Time Using TBM:	3 Work Days
Drilling Time Using Drill & Blast Method:	10 Work Days

Option A:

	Cost	Time (Workdays)
Drill & Blast Storage Areas:	$8,430,629	301
Drill & Blast Entrance Areas:	$701,460	39
Drill & Blast Blast Areas:	$457,665	25
Drill & Blast H & M Areas:	$351,662	10
TBM Main Passageways:	$3,435,545	137

Total Cost Expressed in July 1982 Dollars = $13,376,960

Total Cost Expressed in 1993 Dollars = $16,529,493

Total Number of Workdays = 512

Option B:

	Cost	Time (Workdays)
TBM Storage Areas:	$3,613,127	93
TBM Entrance Areas:	$389,700	16
Drill & Blast Blast Areas:	$457,665	25
Drill & Blast H & M Areas:	$351,662	10
TBM Main Passageways:	$3,435,545	137

Total Cost Expressed in July 1982 Dollars = $8,247,698

Total Cost Expressed in 1993 Dollars = $10,191,424

Total Number of Workdays = 281

FORT CARSON LIFE CYCLE COST ANALYSIS: ALTERNATIVE III

Labor:	$436,800
Average Hourly Rate:	$15.00
Number of Full-Time Workers :	10
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$20,000
Design and Construction:	$16,500,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$1,073,325
EAC of Labor, Equipment, & Maintenance:	$500,800
Equivalent Annual Cost of Alternative III :	**$1,574,125**

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$16,500,000
PV of Labor, Equipment, & Maintenance:	$7,698,298
Present Value of Alternative III :	**$24,198,298**

FORT CARSON LIFE CYCLE COST ANALYSIS: ALTERNATIVE III

Labor:	$436,800
Average Hourly Rate:	$15.00
Number of Full-Time Workers :	10
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$20,000
Design and Construction:	$16,500,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$1,750,320
EAC of Labor, Equipment, & Maintenance:	$500,800
Equivalent Annual Cost of Alternative III :	$2,251,120

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$16,500,000
PV of Labor, Equipment, & Maintenance:	$4,721,042
Present Value of Alternative III :	$21,221,042

YAKIMA TRAINING CENTER ABOVEGROUND EXPANSION: ALTERNATIVE I

Real Estate:	Number of Igloos	3	
	Igloo to Igloo Spacing	270	Feet
	Width of Door Area	10	Feet
	Length of Real Estate Needed	1,110	Feet
	Minimum Igloo Spacing	525	Feet
	Buffer Zone	55	Feet
	Width of Real Estate Needed	580	Feet
	Area of Real Estate Needed	14.78	Acres
	Cost of Real Estate Per Acre	$1,000	
	Total Cost of Real Estate	$14,780	
Site Work:	Length of Maintenance Road	650	Feet
	Width of Maintenance Road	20	Feet
	Length of Service Road	1200	Feet
	Width of Service Road	35	Feet
	Depth of Road Surface	12	Inches
	Cost of Surface per Cubic Yard	$45	
	Cost of Building Roadways	$135,000	
	Cost of Clearing Land per Acre	$1,000	
	Cost of Clearing Land	$14,780	
	Cost of Fence per Foot Length	$20	
	Cost of Fencing in New Area	$56,000	
	Cost of Perimeter Lighting	$120,000	
	Total Cost of Site Work:	$325,780	
Cost of Igloos:	Acquisition Cost: Stradleys	$500,000	Per Igloo
	Total Cost of Igloos Built	$1,500,000	

Total Cost of Expanding Above Ground Storage Facilities: $1,840,559

YAKIMA TRAINING CENTER LCC ANALYSIS: ALTERNATIVE I

Labor:	$326,144
Average Hourly Rate:	$14.00
Number of Full-Time Workers :	8
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$25,000
Maintenance:	$15,000
Design and Construction:	$1,840,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$119,692
EAC of Labor, Equipment, & Maintenance:	$366,144
Equivalent Annual Cost of Alternative I :	$485,836

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$1,840,000
PV of Labor, Equipment, & Maintenance:	$5,628,366
Present Value of Alternative I :	$7,468,366

YAKIMA TRAINING CENTER LCC ANALYSIS: ALTERNATIVE I

Labor:	$326,144
Average Hourly Rate:	$14.00
Number of Full-Time Workers :	8
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$25,000
Maintenance:	$15,000
Design and Construction:	$1,840,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$195,187
EAC of Labor, Equipment, & Maintenance:	$366,144
Equivalent Annual Cost of Alternative I :	$561,331

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$1,840,000
PV of Labor, Equipment, & Maintenance:	$3,451,639
Present Value of Alternative I :	$5,291,639

YAKIMA TRAINING CENTER UNDERGROUND STORAGE: ALTERNATIVE II

STORAGE AREAS:

Number of Storage Cells:	2
Length of Storage Area:	100 Feet
Width of Storage Area:	40 Feet
Radius of Circular Arch:	20 Feet
Height of Wall to Beginning of Circular Arch:	4 Feet
Volume of Storage Areas:	5,839 Cubic Yards
Tunnelling Using TBM:	$75 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$175 Per Cubic Yard
Total Cost Using TBM:	$437,955
Total Cost Using Drill & Blast Technique:	$1,021,894
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	20 Cubic Yards/Hour
Drilling Time Using TBM:	11 Work Days
Drilling Time Using Drill & Blast Method:	36 Work Days

ENTRANCE TO STORAGE AREAS:

Length of Entrance:	150 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of Entrances to Storage Areas:	3,523 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$440,388
Total Cost Using Drill & Blast Technique:	$792,699
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	18 Work Days
Drilling Time Using Drill & Blast Method:	44 Work Days

YAKIMA TRAINING CENTER UNDERGROUND STORAGE: ALTERNATIVE II

Option One:

	Cost	Time (Workdays)
Drill & Blast Storage Areas:	$1,021,894	36
Drill & Blast Entrance Areas:	$792,699	44

Total Cost Expressed in July 1982 Dollars = $1,814,593

Total Cost Expressed in 1993 Dollars = $2,242,237

Total Number of Workdays = 81

Option Two:

	Cost	Time (Workdays)
TBM Storage Areas:	$437,955	11
TBM Entrance Areas:	$440,388	18

Total Cost Expressed in July 1982 Dollars = $878,343

Total Cost Expressed in 1993 Dollars = $1,085,341

Total Number of Workdays = 29

YAKIMA TRAINING CENTER LCC ANALYSIS: ALTERNATIVE II

Labor:	$326,144
Average Hourly Rate:	$14.00
Number of Full-Time Workers :	8
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$25,000
Maintenance:	$15,000
Design and Construction:	$2,240,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$145,712
EAC of Labor, Equipment, & Maintenance:	$366,144
Equivalent Annual Cost of Alternative II :	$511,856

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$2,240,000
PV of Labor, Equipment, & Maintenance:	$5,628,366
Present Value of Alternative II :	$7,868,366

YAKIMA TRAINING CENTER LCC ANALYSIS: ALTERNATIVE II

Labor:	$326,144
Average Hourly Rate:	$14.00
Number of Full-Time Workers :	8
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$25,000
Maintenance:	$15,000
Design and Construction:	$2,240,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$237,619
EAC of Labor, Equipment, & Maintenance:	$366,144
Equivalent Annual Cost of Alternative II :	$603,763

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$2,240,000
PV of Labor, Equipment, & Maintenance:	$3,451,639
Present Value of Alternative II :	$5,691,639

YAKIMA TRAINING CENTER UNDERGROUND STORAGE: ALTERNATIVE III

STORAGE AREAS:

Number of Storage Cells:	6
Length of Storage Area:	100 Feet
Width of Storage Area:	40 Feet
Radius of Circular Arch:	20 Feet
Height of Wall to Beginning of Circular Arch:	4 Feet
Volume of Storage Areas:	17,518 Cubic Yards
Tunnelling Using TBM:	$75 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$175 Per Cubic Yard
Total Cost Using TBM:	$1,313,864
Total Cost Using Drill & Blast Technique:	$3,065,683
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	20 Cubic Yards/Hour
Drilling Time Using TBM:	34 Work Days
Drilling Time Using Drill & Blast Method:	109 Work Days

ENTRANCE TO STORAGE AREAS:

Length of Entrance:	15 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Angle of Entrance wrt Main Passage:	60 Degrees
Actual Length of Entrance Due to Angle:	26.55 Feet
Volume of Entrances to Storage Areas:	1,871 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$233,820
Total Cost Using Drill & Blast Technique:	$420,876
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	9 Work Days
Drilling Time Using Drill & Blast Method:	23 Work Days

YAKIMA TRAINING CENTER UNDERGROUND STORAGE: ALTERNATIVE III

BLAST AREAS:

Length of Entrance:	15 Feet
Width of Entrance:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Actual Length of Entrance Due to Angle:	17.32 Feet
Volume of Blast Areas:	1,220 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$152,555
Total Cost Using Drill & Blast Technique	$274,599
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	6 Work Days
Drilling Time Using Drill & Blast Method:	15 Work Days

MAIN PASSAGEWAY:

Outer Radius of Arch:	95 Feet
Inner Radius of Arch:	75 Feet
Path Length (Along Arch):	267.04 Feet
Distance from Entrance to Rib:	100 Feet
Width of Rib Road:	20 Feet
Distance from Rib to First Storage Cell:	80 Feet
Distance Between Storage Cells:	150 Feet
Length of Rib:	150 Feet
Length of Storage Cell Entrance:	23.09 Feet
Total Length of Main Passages:	1648 Feet
Width of Main Passageway:	20 Feet
Radius of Circular Arch:	10 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of Main Passageways:	19,353 Cubic Yards
Tunnelling Using TBM:	$125 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$225 Per Cubic Yard
Total Cost Using TBM:	$2,419,164
Total Cost Using Drill & Blast Technique:	$4,354,496
Tunnelling Rate Using TBM:	25 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	10 Cubic Yards/Hour
Drilling Time Using TBM:	97 Work Days
Drilling Time Using Drill & Blast Method:	242 Work Days

YAKIMA TRAINING CENTER UNDERGROUND STORAGE: ALTERNATIVE III

HANDLING / MAINTENANCE AREAS:

Number of H&M Areas:	2
Length of H&M Area:	40 Feet
Width of H&M Area	30 Feet
Radius of Circular Arch:	15 Feet
Height of Wall to Beginning of Circular Arch:	8 Feet
Volume of H & M Areas:	1,758 Cubic Yards
Tunnelling Using TBM:	$80 Per Cubic Yard
Tunnelling Using Drill & Blast Method:	$200 Per Cubic Yard
Total Cost Using TBM:	$140,665
Total Cost Using Drill & Blast Technique:	$351,662
Tunnelling Rate Using TBM:	65 Cubic Yards/Hour
Tunnelling Rate Using Drill & Blast Method:	23 Cubic Yards/Hour
Drilling Time Using TBM:	3 Work Days
Drilling Time Using Drill & Blast Method:	10 Work Days

Option A:

	Cost	Time (Workdays)
Drill & Blast Storage Areas:	$3,065,683	109
Drill & Blast Entrance Areas:	$420,876	23
Drill & Blast Blast Areas:	$274,599	15
Drill & Blast H & M Areas:	$351,662	10
TBM Main Passageways:	$2,419,164	97

Total Cost Expressed in July 1982 Dollars = $6,531,984

Total Cost Expressed in 1993 Dollars = $8,071,369

Total Number of Workdays = 254

Option B:

	Cost	Time (Workdays)
TBM Storage Areas:	$1,313,864	34
TBM Entrance Areas:	$233,820	9
Drill & Blast Blast Areas:	$274,599	15
Drill & Blast H & M Areas:	$351,662	10
TBM Main Passageways:	$2,419,164	97

Total Cost Expressed in July 1982 Dollars = $4,593,109

Total Cost Expressed in 1993 Dollars = $5,675,561

Total Number of Workdays = 165

YAKIMA TRAINING CENTER LCC ANALYSIS: ALTERNATIVE III

Labor:	$326,144
Average Hourly Rate:	$14.00
Number of Full-Time Workers :	8
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	40
Percentage of Burden :	40
Equipment:	$25,000
Maintenance:	$15,000
Design and Construction:	$8,070,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$524,954
EAC of Labor, Equipment, & Maintenance:	$366,144
Equivalent Annual Cost of Alternative III :	$891,098

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$8,070,000
PV of Labor, Equipment, & Maintenance:	$5,628,366
Present Value of Alternative III :	$13,698,366

YAKIMA TRAINING CENTER LCC ANALYSIS: ALTERNATIVE III

Labor:	$326,144
Average Hourly Rate:	$14.00
Number of Full-Time Workers :	8
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	40
Percentage of Burden :	40
Equipment:	$25,000
Maintenance:	$15,000
Design and Construction:	$8,070,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 10% interest rate for 30 year period.

A / P :	0.10608
EAC of Construction:	$856,066
EAC of Labor, Equipment, & Maintenance:	$366,144
Equivalent Annual Cost of Alternative III :	**$1,222,210**

PRESENT VALUE (PV) METHOD:

Note: PV Based on 10% interest rate for 30 year period.

P / A :	9.427
PV of Construction:	$8,070,000
PV of Labor, Equipment, & Maintenance:	$3,451,639
Present Value of Alternative III :	**$11,521,639**

YAKIMA TRAINING CENTER ABOVEGROUND EXPANSION: ALTERNATIVE IV

Real Estate:	Number of Igloos	12	
	Igloo to Igloo Spacing	80	Feet
	Width of Door Area	10	Feet
	Length of Real Estate Needed	1,570	Feet
	Minimum Igloo Spacing	540	Feet
	Buffer Zone	100	Feet
	Width of Real Estate Needed	880	Feet
	Area of Real Estate Needed	31.72	Acres
	Cost of Real Estate Per Acre	$1,000	
	Total Cost of Real Estate	$31,717	
Site Work:	Length of Maintenance Road	6,500	Feet
	Width of Maintenance Road	30	Feet
	Depth of Road Surface	12	Inches
	Cost of Surface per Cubic Yard	$45	
	Cost of Building Roadways	$325,000	
	Cost of Fence per Foot Length	$20	
	Cost of Fencing in New Area	$98,000	
	Cost of Perimeter Lighting	$120,000	
	Total Cost of Site Work:	$543,000	
Cost of Igloos:	Acquisition Cost: Stradleys	$310,000	Per Igloo
	Total Cost of Igloos Built	$3,720,000	
Additional Facilities:	Ammo Inspect./Surveill.	$1,900,000	
	Admin. Building	$750,000	

Total Cost of Expanding Above Ground Storage Facilities: $6,944,717

Note: The conceptual cost estimate above compares favorably with the $6.8 million MCA requested at Fort McCoy, WI. for aboveground storage facilities.

YAKIMA TRAINING CENTER LCC ANALYSIS: ALTERNATIVE IV

Labor:	$326,144
Average Hourly Rate:	$14.00
Number of Full-Time Workers :	8
Number of Part-Time Workers :	0
Number of Temporary Workers :	0
Number of Months Temps Present :	0
Percentage of Burden :	40
Equipment:	$44,000
Maintenance:	$15,000
Design and Construction:	$6,790,000

EQUIVALENT ANNUAL COST (EAC) METHOD:

Note: EAC Based on 5% interest rate for 30 year period.

A / P :	0.06505
EAC of Construction:	$441,690
EAC of Labor, Equipment, & Maintenance:	$385,144
Equivalent Annual Cost of Alternative IV :	**$826,834**

PRESENT VALUE (PV) METHOD:

Note: PV Based on 5% interest rate for 30 year period.

P / A :	15.372
PV of Construction:	$6,790,000
PV of Labor, Equipment, & Maintenance:	$5,920,434
Present Value of Alternative IV :	**$12,710,434**

ANNEX C

ANALYTIC HIERARCHY PROCESS

FORT MCCOY

TABLE 1

Relative Weights of the Major Categories of Criteria

	1	2	3	Priorities
1. Operational (OP)	1	7	7	0.778
2. Economical (EC)	1/7	1	1	0.111
3. Environmental (EV)	1/7	1	1	0.111

Inconsistency Ratio: 0.0

TABLE 2

Relative Weights of the Operational Criteria

	1	2	3	4	5	Priorities
1. Safety	1	1	1	1	1	0.177
2. Manuver Space	1	1	5	1/5	1	0.177
3. Security	1	1/5	1	1/5	1/5	0.070
4. Accessibility	1	5	5	1	1	0.351
5. Haul Distance	1	1	5	1	1	0.226

Inconsistency Ratio: 0.148

TABLE 3

Relative Weights of the Economical Criteria

	1	2	Priorities
1. Life Cycle Cost	1	7	0.875
2. Encumbrance	1/7	1	0.125

Inconsistency Ratio: 0.0

TABLE 4

Relative Weights of the Environmental Criteria

	1	2	3	4	Priorities
1. Aesthetics	1	1/5	1/5	1/5	0.057
2. Ecological Impact	5	1	1	1	0.283
3. Terrain Suitability	5	1	1	5	0.464
4. Encroachment	5	1	1/5	1	0.197

Inconsistency Ratio: 0.126

TABLE 5
Relative Ratings of Alternatives Versus Operational Crteria

A. Safety

	I	II	III	IV	Priorities
I	1	1/3	1/9	1/7	0.040
II	3	1	1/9	1/6	0.071
III	9	9	1	5	0.660
IV	7	5	1/6	1	0.229
	IR	0.093			

B. Manuver Space

	I	II	III	IV	Priorities
I	1	5	1/9	3	0.155
II	1/5	1	1/9	1/2	0.045
III	9	9	1	9	0.733
IV	1/3	2	1/9	1	0.068
	IR	0.104			

C. Security

	I	II	III	IV	Priorities
I	1	3	1/9	1/5	0.080
II	1/3	1	1/9	1/4	0.048
III	9	9	1	4	0.640
IV	5	4	1/4	1	0.232
	IR	0.093			

D. Accessibility

	I	II	III	IV	Priorities
I	1	5	3	1	0.410
II	1/5	1	1/5	1/5	0.060
III	1/3	5	1	1	0.232
IV	1	5	1	1	0.298
	IR	0.057			

E. Haul Distance

	I	II	III	IV	Priorities
I	1	1/5	1/9	1/5	0.048
II	5	1	1/3	1/5	0.141
III	9	3	1	1	0.395
IV	5	5	1	1	0.416
	IR	0.083			

TABLE 6

Relative Ratings of Alternatives Versus Economical Criteria

	Alternative I		Alternative II		Alternative III		Alternative IV	
	Data	**Pri**	**Data**	**Pri**	**Data**	**Pri**	**Data**	**Pri**
A. Life Cycle Cost (1000$)	637	.337	680	.315	1298	.165	1174	.183
A. Life Cycle Cost (million$)	6.01	.337	6.41	.315	12.24	.165	11.07	.183
B. Encumbrance (Acres)	645	.112	588	.123	125	.579	390	.186

TABLE 7

Relative Ratings of Alternatives Versus Environmental Criteria

A. Aesthetics

	I	II	III	IV	Priorities
I	1	3	1/9	1	0.106
II	1/3	1	1/9	1/6	0.042
III	9	9	1	7	0.711
IV	1	6	1/7	1	0.141
	IR	0.099			

B. Ecological Impact

	I	II	III	IV	Priorities
I	1	3	1/7	5	0.183
II	1/3	1	1/6	2	0.084
III	7	6	1	9	0.686
IV	1/5	1/2	1/9	1	0.048
	IR	0.084			

C. Terrain Suitability

	I	II	III	IV	Priorities
I	1	1	1/9	1/9	0.046
II	1	1	1/9	1/6	0.049
III	9	9	1	5	0.650
IV	9	6	1/5	1	0.255
	IR	0.101			

D. Encroachment

	I	II	III	IV	Priorities
I	1	1/5	1/9	1/5	0.040
II	5	1	1/9	1/2	0.111
III	9	9	1	5	0.678
IV	5	2	1/5	1	0.171
	IR	0.099			

Table 8

Weighted Ratings for Operational Factors

	5A	5B	5C	5D	5E			
I	0.040	0.155	0.080	0.410	0.048		0.177	OP Priority Vector
II	0.071	0.045	0.048	0.060	0.141	x	0.177	
III	0.660	0.733	0.640	0.232	0.395		0.070	= (I- 0.195, II-0.077, III-0.461,IV-0.267)
IV	0.229	0.068	0.232	0.298	0.416		0.351	
							0.226	

Weighted Ratings for Economical Factors

	6A	6B			
					EC Priority Vector
I	0.337	0.112	x	0.875	
II	0.315	0.123		0.125	= (I-0.309, II-0.291, III-0.217, IV-0.183)
III	0.165	0.579			
IV	0.183	0.186			

Weighted Ratings for Environmental Factors

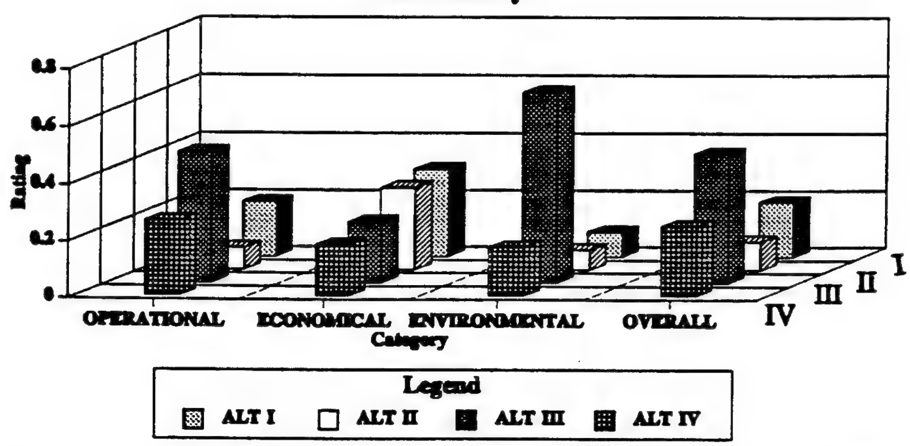
7A	7B	7C	7D			
I	0.106	0.183	0.046	0.040		.057	EV Priority Vector
II	0.042	0.084	0.049	0.111	x	0.283	
III	0.711	0.686	0.650	0.678		0.464	= (I-0.087, II-0.071, III-0.669, IV-0.174)
IV	0.141	0.048	0.255	0.171		0.197	

Overall Ratings of Alternatives

	OP	EC	EV			
						Overall Priority Vector
I	0.195	0.309	0.087		0.778	
II	0.077	0.291	0.071	x	0.111	= (I-0.195, II-0.100, III-0.457, IV-0.248)
III	0.461	0.217	0.669		0.111	
IV	0.267	0.183	0.174			

AHP RESULTS

Fort McCoy



ALT I	0.195	0.309	0.067	0.195
ALT II	0.077	0.291	0.071	0.1
ALT III	0.461	0.217	0.669	0.457
ALT IV	0.267	0.183	0.174	0.248

Figure C-1 Fort McCoy AHP Summary

FORT DRUM

TABLE 1

Relative Weights of the Major Categories of Criteria

	1	2	3	Priorities
1. Operational (OP)	1	7	5	0.715
2. Economical (EC)	1/7	1	1/5	0.067
3. Environmental (EV)	1/5	5	1	0.218

Inconsistency Ratio: 0.158

TABLE 2

Relative Weights of the Operational Criteria

	1	2	3	4	5	Priorities
1. Safety	1	3	3	5	7	0.458
2. Manuver Space	1/3	1	1/2	1	1	0.101
3. Security	1/3	3	1	5	7	0.294
4. Accessibility	1/5	1	1/5	1	3	0.093
5. Haul Distance	1/7	1	1/7	1/3	1	0.054

Inconsistency Ratio: 0.096

TABLE 3

Relative Weights of the Economical Criteria

	1	2	Priorities
1. Life Cycle Cost	1	7	0.875
2. Encumbrance	1/7	1	0.125

Inconsistency Ratio: 0.0

TABLE 4

Relative Weights of the Environmental Criteria

	1	2	3	4	Priorities
1. Aesthetics	1	1/9	1/7	1/7	0.037
2. Ecological Impact	9	1	1	1/3	0.239
3. Terrain Suitability	7	1	1	3	0.409
4. Encroachment	7	3	1/3	1	0.315

Inconsistency Ratio: 0.196

TABLE 5
Relative Ratings of Alternatives Versus Operational Crteria

A. Safety

	I	II	III	Priorities
I	1	1/3	1/9	0.070
II	3	1	1/5	0.178
III	9	5	1	0.751
	IR	0.017		

B. Manuver Space

	I	II	III	Priorities
I	1	5	1/6	0.188
II	1/5	1	1/9	0.056
III	6	9	1	0.756
	IR	0.094		

C. Security

	I	II	III	Priorities
I	1	5	1/5	0.207
II	1/5	1	1/9	0.058
III	5	9	1	.735
	IR	0.101		

D. Accessibility

	I	II	III	Priorities
I	1	3	3	0.600
II	1/3	1	1	0.200
III	1/3	1	1	0.200
	IR	0.0		

E. Haul Distance

	I	II	III	Priorities
I	1	2	3	0.528
II	1/2	1	3	0.333
III	1/3	1/3	1	0.140
	IR	0.046		

TABLE 6

Relative Ratings of Alternatives Versus Economical Criteria

	Alternative I		Alternative II		Alternative III		Alternative IV	
	Data	Pri	Data	Pri	Data	Pri	Data	Pri
A. Life Cycle Cost (1000$)	876	.425	911	.410	2259	.165	na	
A. Life Cycle Cost (millons)	8.26	.425	8.58	.410	21.30	.165	na	
B. Encumbrance (Acres)	496	.162	631	.127	113	.711	na	

TABLE 7

Relative Ratings of Alternatives Versus Environmental Criteria

A. Aesthetics

	I	II	III	Priorities
I	1	3	1/8	0.138
II	1/3	1	1/9	0.064
III	8	9	1	0.798
	IR	0.093		

B. Ecological Impact

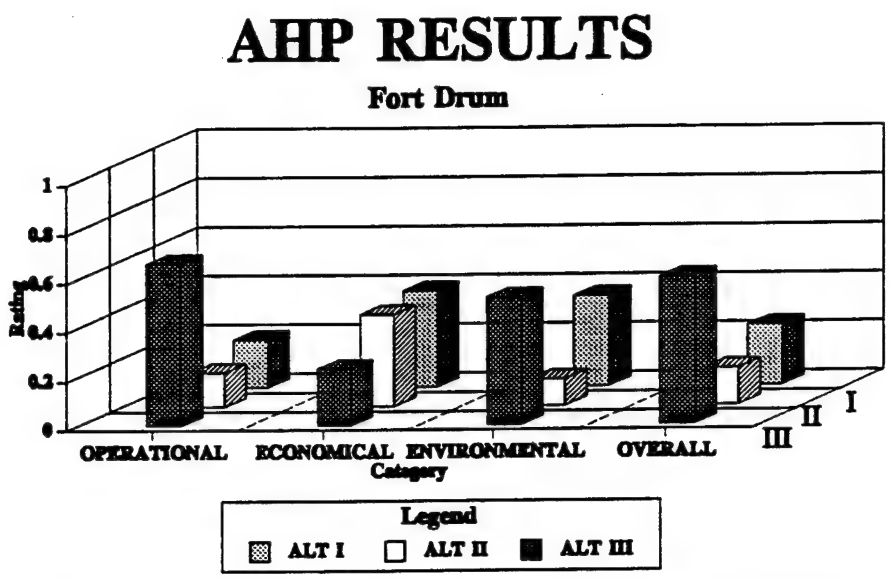
	I	II	III	Priorities
I	1	3	1/8	0.138
II	1/3	1	1/9	0.064
III	8	9	1	0.798
	IR	0.093		

C. Terrain Suitability

	I	II	III	Priorities
I	1	5	3	0.659
II	1/5	1	1	0.156
III	1/3	1	1	0.185
	IR	0.025		

D. Encroachment

	I	II	III	Priorities
I	1	3	1/5	0.195
II	1/3	1	1/6	0.088
III	5	6	1	0.717
	IR	0.081		



ALT I	0.196	0.393	0.369	0.247
ALT II	0.141	0.374	0.109	0.15
ALT III	0.663	0.233	0.522	0.603

Figure C-2 Fort Drum AHP Summary

TABLE 8

Weighted Ratings for Operational Factors

	5A	5B	5C	5D	5E			OP Priority Vector
I	0.070	0.188	0.207	0.600	0.528		0.458	
II	0.178	0.056	0.058	0.200	0.333	x	0.101	
III	0.751	0.756	0.735	0.200	0.140		0.294	=(I-0.196, II-0.141, III-0.663)
							0.093	
							0.054	

Weighted Ratings for Economical Factors

	6A	6B			EC Priority Vector
I	0.425	0.162		0.875	
II	0.410	0.127	x	0.125	= (I-0.393, II-0.374, III-0.233)
III	0.165	0.711			

Weighted Ratings for Environmental Factors

	7A	7B	7C	7D			EV Priority Vector
I	0.138	0.138	0.659	0.195		0.037	
II	0.064	0.064	0.156	0.088	x	0.239	= (I-0.369, II-0.109, III-0.522)
III	0.798	0.798	0.185	0.717		0.409	
						0.315	

Overall Ratings of Alternatives

	OP	EC	EV			Overall Priority Vector
I	0.196	0.393	0.369		0.715	
II	0.141	0.374	0.109	x	0.067	= (I-0.247, II-0.150, III-0.603)
III	0.663	0.233	0.522		0.218	

FORT DIX

TABLE 1

Relative Weights of the Major Categories of Criteria

	1	2	3	Priorities
1. Operational (OP)	1	1	3	0.429
2. Economical (EC)	1	1	3	0.429
3. Environmental (EV)	1/3	1/3	1	0.143

Consistency Ratio: 0.0

TABLE 2

Relative Weights of the Operational Criteria

	1	2	3	4	5	Priorities
1. Safety	1	7	1	1/3	1/5	0.136
2. Manuver Space	1/7	1	1/3	1/3	1/7	0.044
3. Security	1	3	1	3	5	0.352
4. Accessibility	3	3	1/3	1	5	0.277
5. Haul Distance	5	7	1/5	1/5	1	0.191

Consistency Ratio: 0.407

TABLE 3

Relative Weights of the Economical Criteria

	1	4	Priorities
1. Life Cycle Cost	1	7	0.875
2. Encumbrance	1/7	1	0.125

Consistency Ratio: 0.0

TABLE 4

Relative Weights of the Environmental Criteria

	1	2	3	4	Priorities
1. Aesthetics	1	3	1	1/5	0.178
2. Ecological Impact	1/3	1	3	1/5	0.135
3. Terrain Suitability	1	1/3	1	1/5	0.098
4. Encroachment	5	5	5	1	0.589

Consistency Ratio: 0.180

TABLE 5
Relative Ratings of Alternatives Versus Operational Crteria

A. Safety

	I	IV	Priorities
I	1	1/8	0.111
IV	8	1	0.889

B. Manuver Space

	I	IV	Priorities
I	1	9	0.900
IV	1/9	1	0.100

C. Security

	I	IV	Priorities
I	1	1/9	0.100
IV	9	1	0.900

D. Accessibility

	I	IV	Priorities
I	1	1/5	0.167
IV	5	1	0.833

E. Haul Distance

	I	IV	Priorities
I	1	1/9	0.100
IV	9	1	0.900

TABLE 6

Relative Ratings of Alternatives Versus Economical Criteria

	Alternative I		Alternative IV	
	Data	Priority	Data	Priority
A. Life Cycle Cost (1000$)	0.0$	0.900	>0.0$	0.100
A. Life Cycle Cost (million)	na	na	na	na
B. Encumbrance (AC)	441	0.540	518	0.460

TABLE 7

Relative Ratings of Alternatives Versus Environmental Criteria

A. Aesthetics

	I	IV	Priorities
I	1	1/3	0.250
IV	3	1	0.750
	IR	0.0	

B. Ecological Impact

	I	IV	Priorities
I	1	5	0.833
IV	1/5	1	0.167
	IR	0.0	

C. Terrain Suitability

	I	IV	Priorities
I	1	1/3	0.250
IV	3	1	0.750
	IR	0.0	

D. Encroachment

	I	IV	Priorities
I	1	1/9	0.100
IV	9	1	0.900
	IR	0.0	

TABLE 8

Weighted Ratings for Operational Factors

	5A	5B	5C	5D	5E				
I	0.11	0.90	0.10	0.167	0.10		0.136		OP Priority Vector
IV	0.89	0.10	0.90	0.833	0.90	x	0.044		
							0.352	=	(I-0.155, IV-0.845)
							0.277		
							0.191		

Weighted Ratings for Economical Factors

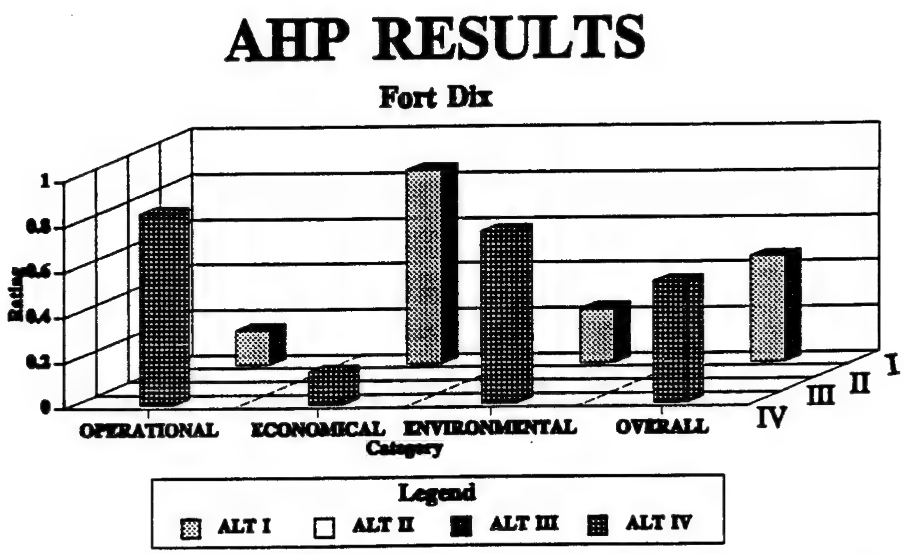
	6A	6B				
						EC Priority Vector
I	0.900	0.540		0.875		
IV	0.100	0.460	x	0.125	=	(I-0.855, IV-0.145)

Weighted Ratings for Environmental Factors

	7A	7B	7C	7D				
								EV Priority Vector
I	0.25	0.833	0.25	0.10		0.178		
IV	0.75	0.167	0.75	0.90	x	0.135	=	(I-0.240, IV-0.760)
						0.098		
						0.589		

Overall Ratings of Alternatives

	OP	EC	EV				
							Overall Priority Vector
I	0.155	0.855	0.240		0.429		
IV	0.845	0.145	0.760	x	0.429	=	(I-0.467, IV-0.533)
					0.143		



ALT I	0.155	0.855	0.24	0.467
ALT II	NA	NA	NA	NA
ALT III	NA	NA	NA	NA
ALT IV	0.845	0.145	0.76	0.533

Figure C-3 Fort Dix AHP Summary

FORT KNOX

TABLE 1

Relative Weights of the Major Categories of Criteria

	1	2	3	Priorities
1. Operational (OP)	1	5	5	0.714
2. Economical (EC)	1/5	1	1	0.143
3. Environmental (EV)	1/5	1	1	0.143

Inconsistency Ratio: 0.0

TABLE 2

Relative Weights of the Operational Criteria

	1	2	3	4	5	Priorities
1. Safety	1	9	9	9	9	0.659
2. Manuver Space	1/9	1	1/9	1	1	0.037
3. Security	1/9	9	1	9	9	0.230
4. Accessibility	1/9	1	1/9	1	1	0.037
5. Haul Distance	1/9	1	1/9	1	1	0.037

Inconsistency Ratio: 0.148

TABLE 3

Relative Weights of the Economical Criteria

	1	2	Priorities
1. Life Cycle Cost	1	7	0.875
4. Encumbrance	1/7	1	0.125

Inconsistency Ratio: 0.0

TABLE 4

Relative Weights of the Environmental Criteria

	1	2	3	4	Priorities
1. Aesthetics	1	1	1/7	1/9	0.057
2. Ecological Impact	1	1	1/7	1/7	0.061
3. Terrain Suitability	7	7	1	1	0.427
4. Encroachment	9	7	1	1	0.455

Inconsistency Ratio: 0.003

TABLE 5
Relative Ratings of Alternatives Versus Operational Crteria

A. Safety

	I	II	III	Priorities
I	1	1/3	1/9	0.066
II	3	1	1/7	0.149
III	9	7	1	0.785
	IR	0.046		

D. Accessibility

	I	II	III	Priorities
I	1	7	1	0.487
II	1/7	1	1/5	0.078
III	1	5	1	0.435
	IR	0.069		

B. Manuver Space

	I	II	III	Priorities
I	1	3	1/7	0.149
II	1/3	1	1/9	0.066
III	7	9	1	0.785
	IR	0.069		

E. Haul Distance

	I	II	III	Priorities
I	1	1/7	1/9	0.055
II	7	1	1/3	0.290
III	9	3	1	0.655
	IR	0.069		

C. Security

	I	II	III	Priorities
I	1	2	1/9	0.114
II	1/2	1	1/9	0.072
III	9	9	1	0.814
	IR	0.046		

TABLE 6

Relative Ratings of Alternatives Versus Economical Criteria

	Alternative I		Alternative II		Alternative III		Alternative IV	
	Data	Pri	Data	Pri	Data	Pri	Data	Pri
A. Life Cycle Cost (1000$)	679	.473	863	.372	2061	.155	na	
A. Life Cycle Cost(million$)	6.40	.473	8.14	.372	19.4	.155	na	
B. Encumbrance (Acres)	1151	.082	1286	.073	111	.845	na	

TABLE 7

Relative Ratings of Alternatives Versus Environmental Criteria

A. Aesthetics

	I	II	III	Priorities
I	1	8	1/9	0.174
II	1/8	1	1/9	0.043
III	9	9	1	0.783
	IR	0.431		

B. Ecological Impact

	I	II	III	Priorities
I	1/6	1	1/9	0.160
II	1/6	1	1/9	0.048
III	9	9	1	0.792
	IR	0.317		

C. Terrain Suitability

	I	II	III	Priorities
I	1	1/6	1/9	0.056
II	6	1	1/4	0.243
III	9	4	1	0.701
	IR	0.093		

D. Encroachment

	I	II	III	Priorities
I	1	1/5	1/9	0.058
II	5	1	1/5	0.207
III	9	5	1	0.735
	IR	0.101		

TABLE 8

Weighted Ratings for Operational Factors

$$\begin{array}{c} \\ \mathrm{I} \\ \mathrm{II} \\ \mathrm{III} \\ \\ \\ \end{array} \begin{array}{ccccc} 5A & 5B & 5C & 5D & 5E \\ 0.066 & 0.149 & 0.114 & 0.487 & 0.055 \\ 0.149 & 0.066 & 0.072 & 0.078 & 0.290 \\ 0.785 & 0.785 & 0.814 & 0.435 & 0.655 \\ & & & & \\ & & & & \end{array} \times \begin{array}{c} 0.659 \\ 0.037 \\ 0.230 \\ 0.037 \\ 0.037 \end{array} = $$

OP Priority Vector

(I-0.095, II-0.131, III-0.774)

Weighted Ratings for Economical Factors

$$\begin{array}{c} \\ \mathrm{I} \\ \mathrm{II} \\ \mathrm{III} \end{array} \begin{array}{cc} 6A & 6B \\ 0.473 & 0.082 \\ 0.372 & 0.073 \\ 0.155 & 0.845 \end{array} \times \begin{array}{c} 0.875 \\ 0.125 \end{array} = $$

EC Priority Vector

(I-0.424, II-0.335, III-0.241)

Weighted Ratings for Environmental Factors

$$\begin{array}{c} \\ \mathrm{I} \\ \mathrm{II} \\ \mathrm{III} \\ \\ \end{array} \begin{array}{cccc} 7A & 7B & 7C & 7D \\ 0.174 & 0.160 & 0.056 & 0.058 \\ 0.043 & 0.048 & 0.243 & 0.207 \\ 0.783 & 0.792 & 0.701 & 0.735 \\ & & & \end{array} \times \begin{array}{c} 0.057 \\ 0.061 \\ 0.427 \\ 0.455 \end{array} = $$

EV Priority Vector

(I-0.070, II-0.203, III-0.727)

Overall Ratings of Alternatives

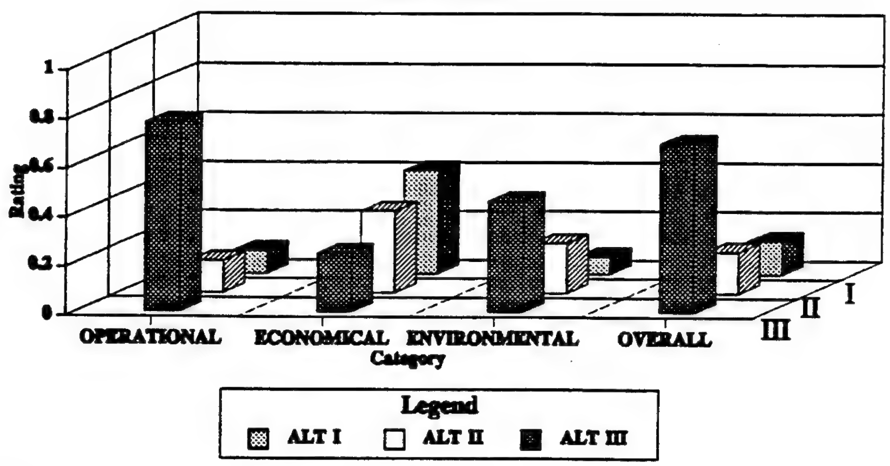
$$\begin{array}{c} \\ \mathrm{I} \\ \mathrm{II} \\ \mathrm{III} \end{array} \begin{array}{ccc} OP & EC & EV \\ 0.095 & 0.424 & 0.070 \\ 0.131 & 0.335 & 0.203 \\ 0.774 & 0.241 & 0.727 \end{array} \times \begin{array}{c} 0.714 \\ 0.143 \\ 0.143 \end{array} = $$

Overall Priority Vector

(I-0.139, II-0.170, III-0.691)

AHP RESULTS

Fort Knox



ALT I	0.095	0.424	0.07	0.139
ALT II	0.131	0.335	0.263	0.17
ALT III	0.774	0.241	0.455	0.691

FORT HUACHUCA

TABLE 1

Relative Weights of the Major Categories of Criteria

	1	2	3	Priorities
1. Operational (OP)	1	5	1	0.527
2. Economical (EC)	1/5	1	3	0.260
3. Environmental (EV)	1	1/3	1	0.214

Inconsistency Ratio: 0.751

TABLE 2

Relative Weights of the Operational Criteria

	1	2	3	4	5	Priorities
1. Safety	1	7	1	3	7	0.338
2. Manuver Space	1/7	1	1/7	1/5	1/5	0.033
3. Security	1	7	1	5	7	0.398
4. Accessibility	1/3	5	1/5	1	7	0.169
5. Haul Distance	1/9	5	1/7	1/7	1	0.061

Inconsistency Ratio: 0.139

TABLE 3

Relative Weights of the Economical Criteria

	1	2	Priorities
1. Life Cycle Cost	1	7	0.875
2. Encumbrance	1/7	1	0.125

Inconsistency Ratio: 0.0

TABLE 4

Relative Weights of the Environmental Criteria

	1	2	3	4	Priorities
1. Aesthetics	1	1/5	1/7	1/5	0.050
2. Ecological Impact	5	1	1	1	0.280
3. Terrain Suitability	7	1	1	5	0.481
4. Encroachment	5	1	1/5	1	0.190

Inconsistency Ratio: 0.104

TABLE 5

Relative Ratings of Alternatives Versus Operational Crteria

A. Safety

	II	III	IV	Priorities
II	1	1/9	1/7	0.055
III	9	1	3	0.655
IV	7	1/3	1	0.290
	IR	0.069		

B. Manuver Space

	II	III	IV	Priorities
II	1	1/9	1/5	0.060
III	9	1	4	0.709
IV	5	1/4	1	0.231
	IR	0.061		

C. Security

	II	III	IV	Priorities
II	1	1/9	1/5	0.058
III	9	1	5	0.735
IV	5	1/5	1	0.207
	IR	0.043		

D. Accessibility

	II	III	IV	Priorities
II	1	1/9	1/7	0.059
III	9	1	1	0.490
IV	7	1	1	0.451
	IR	0.004		

E. Haul Distance

	II	III	IV	Priorities
II	1	1	1	0.333
III	1	1	1	0.333
IV	1	1	1	0.333
	IR	0.0		

TABLE 6

Relative Ratings of Alternatives Versus Economical Criteria

	Alternative I		Alternative II		Alternative III		Alternative IV	
	Data	Pri	Data	Pri	Data	Pri	Data	Pri
A. Life Cycle Cost (1000$)	na		457	.523	1076	.223	941	.254
A. Life Cycle Cost (millons)	na		4.31	.523	10.14	.223	8.87	.254
B. Encumbrance (Acres)	na		573	.136	125	.623	324	.241

TABLE 7

Relative Ratings of Alternatives Versus Environmental Criteria

A. Aesthetics

	II	III	IV	Priorities
II	1	1/9	1/7	0.055
III	9	1	3	0.655
IV	7	1/3	1	0.290
	IR	0.069		

B. Ecological Impact

	II	III	IV	Priorities
II	1	1/9	1/5	0.060
III	9	1	4	0.709
IV	5	1/4	1	0.231
	IR	0.061		

C. Terrain Suitability

	II	III	IV	Priorities
II	1	1/9	1/9	0.053
III	9	1	1	0.474
III	9	1	1	0.474
	IR	0.0		

D. Encroachment

	II	III	IV	Priorities
II	1	1/9	1/7	0.055
III	9	1	3	0.655
IV	7	1/3	1	0.290
	IR	0.069		

TABLE 8

Weighted Ratings for Operational Factors

	5A	5B	5C	5D	5E				
II	0.055	0.060	0.058	0.059	0.333		0.338		OP Priority Vector
III	0.655	0.709	0.735	0.490	0.333	x	0.033		
IV	0.290	0.231	0.207	0.451	0.333		0.398	=	(II-0.074, III-0.641, IV-0.285)
							0.169		
							0.061		

Weighted Ratings for Economical Factors

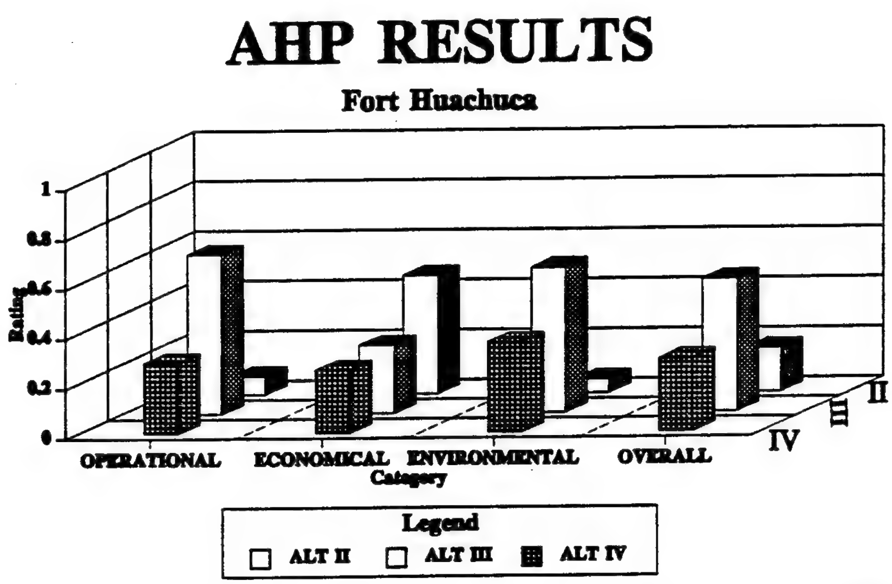
	6A	6B				
						EC Priority Vector
II	0.523	0.136		0.875		
III	0.223	0.623	x	0.125	=	(II-0.475, III-0.273, IV-0.252)
IV	.254	0.241				

Weighted Ratings for Environmental Factors

	7A	7B	7C	7D				
								EV Priority Vector
II	0.055	0.060	0.053	0.055		0.050		
III	0.655	0.709	0.474	0.655	x	0.280	=	(II-0.055, III-0.583, IV-0.362)
IV	0.290	0.231	0.474	0.290		0.481		
						0.190		

Overall Ratings of Alternatives

	OP	EC	EV				
							Overall Priority Vector
II	0.074	0.475	0.055		0.527		
III	0.641	0.273	0.583	x	0.260	=	(I-0.174, II-0.533, III-0.293)
IV	0.285	0.252	0.362		0.214		



ALT II	0.074	0.475	0.055	0.174
ALT III	0.641	0.273	0.583	0.533
ALT IV	0.285	0.252	0.362	0.293

Figure C-5 Fort Huachuca AHP Summary

FORT CARSON

TABLE 1

Relative Weights of the Major Categories of Criteria

	1	2	3	Priorities
1. Operational (OP)	1	5	1	0.519
2. Economical (EC)	1/5	1	5	0.304
3. Environmental (EV)	1	1/5	1	0.177

Inconsistency Ratio: 1.091

TABLE 2

Relative Weights of the Operational Criteria

	1	2	3	4	5	Priorities
1. Safety	1	9	1/5	5	3	0.284
2. Manuver Space	1/9	1	1	1	1	0.108
3. Security	5	1	1	9	7	0.461
4. Accessibility	1/5	1	1/9	1	5	0.087
5. Haul Distance	1/3	1	1/7	1	1	0.060

Inconsistency Ratio: 0.429

TABLE 3

Relative Weights of the Economical Criteria

	1	2	Priorities
1. Life Cycle Cost	1	7	0.875
2. Encumbrance	1/7	1	0.125

Inconsistency Ratio: 0.0

TABLE 4

Relative Weights of the Environmental Criteria

	1	2	3	4	Priorities
1. Aesthetics	1	1/7	1/7	1/7	0.037
2. Ecological Impact	7	1	5	5	0.584
3. Terrain Suitability	7	1/5	1	1	0.261
4. Encroachment	7	1/5	1/5	1/5	0.117

Inconsistency Ratio: 0.253

TABLE 5
Relative Ratings of Alternatives Versus Operational Crteria

A. Safety

	I	II	III	Priorities
I	1	1/3	1/9	0.068
II	3	1	1/6	0.162
III	9	6	1	0.770
	IR	0.046		

B. Manuver Space

	I	II	III	Priorities
I	1	3	1/8	0.138
II	1/3	1	1/9	0.064
III	8	9	1	0.798
	IR	0.093		

C. Security

	I	II	III	Priorities
I	1	5	1/5	0.207
II	1/5	1	1/9	0.058
III	5	9	1	.735
	IR	0.101		

D. Accessibility

	I	II	III	Priorities
I	1	6	1	0.452
II	1/6	1	1/7	0.072
III	1	7	1	0.476
	IR	0.002		

E. Haul Distance

	I	II	III	Priorities
I	1	1/3	1/3	0.140
II	3	1	2	0.528
III	3	1/2	1	0.333
	IR	0.046		

TABLE 6
Relative Ratings of Alternatives Versus Economical Criteria

	Alternative I		Alternative II		Alternative III		Alternative IV	
	Data	Pri	Data	Pri	Data	Pri	Data	Pri
A. Life Cycle Cost (1000$)	607	.471	712	.402	2251	.127	na	
A. Life Cycle Cost (millons)	5.72	.471	6.71	.402	21.2	.127	na	
B. Encumbrance (Acres)	945	.094	1080	.082	108	.824	na	

TABLE 7

Relative Ratings of Alternatives Versus Environmental Criteria

A. Aesthetics

	I	II	III	Priorities
I	1	2	1/9	0.114
II	1/2	1	1/9	0.072
III	9	9	1	0.814
	IR	0.046		

C. Terrain Suitability

	I	II	III	Priorities
I	1	1	1/7	0.111
II	1	1	1/7	0.111
III	7	7	1	0.778
	IR	0.0		

B. Ecological Impact

	I	II	III	Priorities
I	1	5	1/5	0.207
II	1/5	1	1/9	0.058
III	5	9	1	0.735
	IR	0.101		

D. Encroachment

	I	II	III	Priorities
I	1	1/3	1/9	0.066
II	3	1	1/7	0.149
III	9	7	1	0.785
	IR	0.069		

TABLE 8

Weighted Ratings for Operational Factors

	5A	5B	5C	5D	5E				
I	0.068	0.138	0.207	0.452	0.14		0.284		OP Priority Vector
II	0.162	0.064	0.058	0.072	0.528	x	0.108		
III	0.770	0.798	0.735	0.476	0.333		0.461	=	(I-0.177, II-0.118, III-0.705)
							0.087		
							0.06		

Weighted Ratings for Economical Factors

	6A	6B				
						EC Priority Vector
I	0.471	0.094		0.875		
II	0.402	0.082	x	0.125	=	(I-0.424, II-0.362, III-0.214)
III	.127	0.824				

Weighted Ratings for Environmental Factors

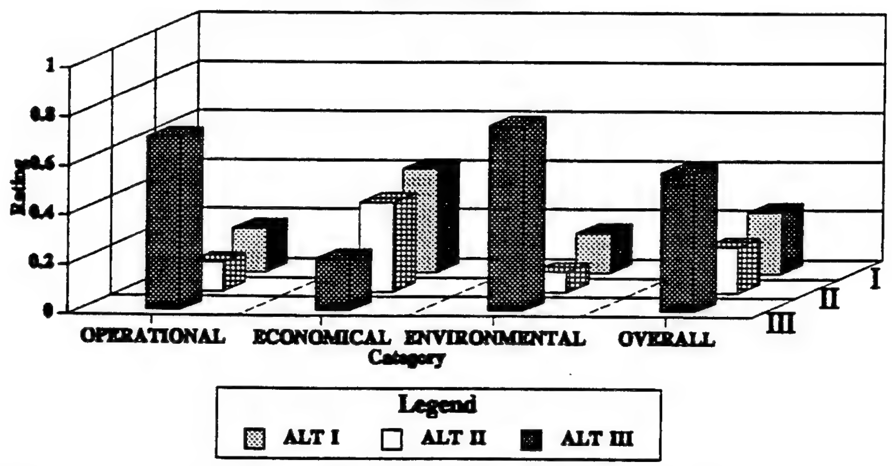
	7A	7B	7C	7D				
								EV Priority Vector
I	0.114	0.207	0.111	0.066		0.037		
II	0.072	0.058	0.111	0.149	x	0.584	=	(I-0.162, II-0.083, III-0.755)
III	0.814	0.735	0.778	0.785		0.261		
IV	0.277	0.040	0.191	0.304		0.117		

Overall Ratings of Alternatives

	OP	EC	EV			
						Overall Priority Vector
I	0.177	0.424	0.162		0.519	
II	0.118	0.362	0.083	x	0.304	= (I-0.249, II-0.186, III-0.565)
III	0.705	0.214	0.755		0.177	

AHP RESULTS

Fort Carson



ALT I	0.177	0.424	0.162	0.249
ALT II	0.118	0.362	0.083	0.186
ALT III	0.705	0.214	0.755	0.565

Figure C-6 Fort Carson AHP Summary

YAKIMA TRAINING CENTER

TABLE 1

Relative Weights of the Major Categories of Criteria

	1	2	3	Priorities
1. Operational (OP)	1	1	3	0.460
2. Economical (EC)	1	1	1/3	0.221
3. Environmental (EV)	1/3	3	1	0.319

Inconsistency Ratio: 0.483

TABLE 2

Relative Weights of the Operational Criteria

	1	2	3	4	5	Priorities
1. Safety	1	9	9	9	9	0.577
2. Manuver Space	1/9	1	1/9	1/7	7	0.050
3. Security	1/9	9	1	9	9	0.248
4. Accessibility	1/9	7	1/9	1	5	0.092
5. Haul Distance	1/9	1/7	1/5	1	1	0.032

Inconsistency Ratio: 0.577

TABLE 3

Relative Weights of the Economical Criteria

	1	2	Priorities
1. Life Cycle Cost	1	7	0.875
2. Encumbrance	1/7	1	0.125

Inconsistency Ratio: 0.0

TABLE 4

Relative Weights of the Environmental Criteria

	1	2	3	4	Priorities
1. Aesthetics	1	1/7	1/7	1/9	0.035
2. Ecological Impact	7	1	9	9	0.696
3. Terrain Suitability	7	1/9	1	2	0.148
4. Encroachment	9	1/9	1/2	1	0.122

Inconsistency Ratio: 0.308

TABLE 5

Relative Ratings of Alternatives Versus Operational Crteria

A. Safety

	I	II	III	IV	Priorities
I	1	1/3	1/9	1/3	0.049
II	3	1	1/9	1/3	0.086
III	9	9	1	7	0.710
IV	3	3	1/7	1	0.156

IR 0.091

B. Manuver Space

	I	II	III	IV	Priorities
I	1	5	1/8	1	0.131
II	1/5	1	1/9	1/5	0.040
III	8	9	1	6	0.691
IV	1	5	1/6	1	0.138

IR 0.090

C. Security

	I	II	III	IV	Priorities
I	1	3	1/8	1/5	0.079
II	1/3	1	1/9	1/6	0.043
III	8	9	1	4	0.627
IV	5	6	1/4	1	0.251

IR 0.085

D. Accessibility

	I	II	III	IV	Priorities
I	1	3	1/6	1/2	0.108
II	1/3	1	1/8	1/7	0.045
III	6	8	1	5	0.639
IV	2	7	1/5	1	0.207

IR 0.075

E. Haul Distance

	I	II	III	IV	Priorities
I	1	1	1	1	0.250
II	1	1	1	1	0.250
III	1	1	1	1	0.250
IV	1	1	1	1	0.250

IR 0.0

TABLE 6

Relative Ratings of Alternatives Versus Economical Criteria

	Alternative I		Alternative II		Alternative III		Alternative IV	
	Data	Pri	Data	Pri	Data	Pri	Data	Pri
A. Life Cycle Cost (1000$)	561	.345	604	.321	1222	.159	1108	.175
A. Life Cycle Cost (million$)	5.29	.345	5.69	.321	11.52	.159	10.45	.175
B. Encumbrance (Acres)	803	.095	746	.102	125	.608	390	.195

TABLE 7

Relative Ratings of Alternatives Versus Environmental Criteria

A. Aesthetics

	I	II	III	IV	Priorities
I	1	1/3	1/9	1/4	0.044
II	3	1	1/9	1/2	0.087
III	9	9	1	9	0.735
IV	4	2	1/9	1	0.134
	IR	0.090			

B. Ecological Impact

	I	II	III	IV	Priorities
I	1	3	1/9	1/3	0.086
II	1/3	1	1/9	1/3	0.049
III	9	9	1	7	0.710
IV	3	3	1/7	1	0.156
	IR	0.091			

C. Terrain Suitability

	I	II	III	IV	Priorities
I	1	1/3	1/6	1/3	0.060
II	3	1	1/7	1	0.123
III	6	7	1	9	0.700
IV	3	1	1/9	1	0.117
	IR	0.094			

D. Encroachment

	I	II	III	IV	Priorities
I	1	1/4	1/9	1/5	0.042
II	4	1	1/7	1/2	0.107
III	9	7	1	7	0.691
IV	5	2	1/7	1	0.160
	IR	0.091			

TABLE 8

Weighted Ratings for Operational Factors

	5A	5B	5C	5D	5E				OP Priority Vector
I	0.049	0.131	0.079	0.108	0.250		0.577		
II	0.086	0.040	0.043	0.045	0.250		0.050		
III	0.710	0.691	0.627	0.639	0.250	x	0.248	=	(I-0.073, II-0.074, III-0.667,IV-0.186)
IV	0.156	0.138	0.251	0.207	0.250		0.092		
							0.032		

Weighted Ratings for Economical Factors

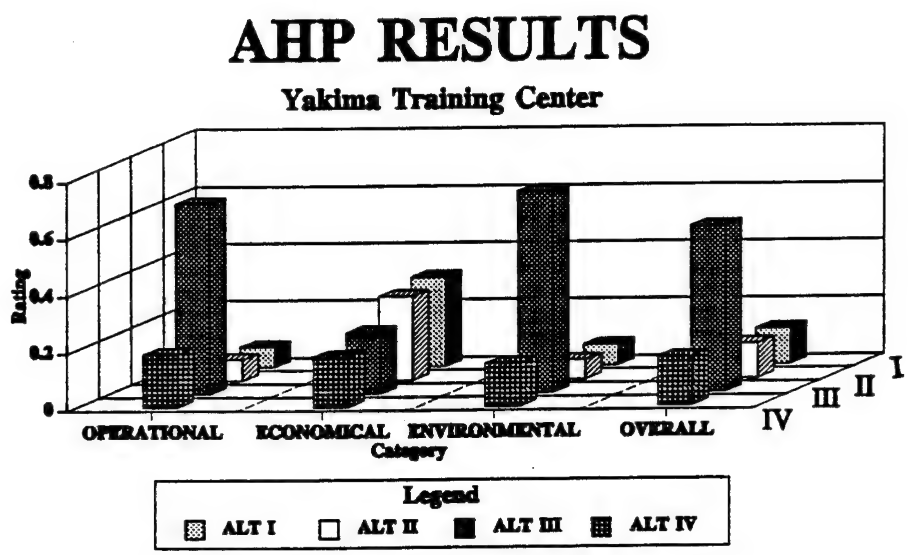
	6A	6B				EC Priority Vector
I	0.345	0.095		0.875		
II	0.321	0.103	x	0.125	=	(I-0.314, II-0.294, III-0.215, IV-0.177)
III	0.159	0.607				
IV	0.175	0.195				

Weighted Ratings for Environmental Factors

	7A	7B	7C	7D				EV Priority Vector
I	0.044	0.086	0.060	0.042		0.035		
II	0.087	0.049	0.123	0.107	x	0.696	=	(I-0.075, II-0.068, III-0.707, IV-0.150)
III	0.735	0.710	0.700	0.691		0.148		
IV	0.134	0.156	0.117	0.160		0.122		

Overall Ratings of Alternatives

	OP	EC	EV				Overall Priority Vector
I	0.073	0.314	0.075		0.460		
II	0.074	0.294	0.068	x	0.221	=	(I-0.127, II-0.121, III-0.580, IV-0.173)
III	0.667	0.215	0.707		0.319		
IV	0.186	0.177	0.150				



ALT I	0.073	0.314	0.075	0.127
ALT II	0.074	0.294	0.068	0.121
ALT III	0.667	0.215	0.707	0.58
ALT IV	0.186	0.177	0.15	0.173

Figure C-7 Yakima Training Center AHP Summary

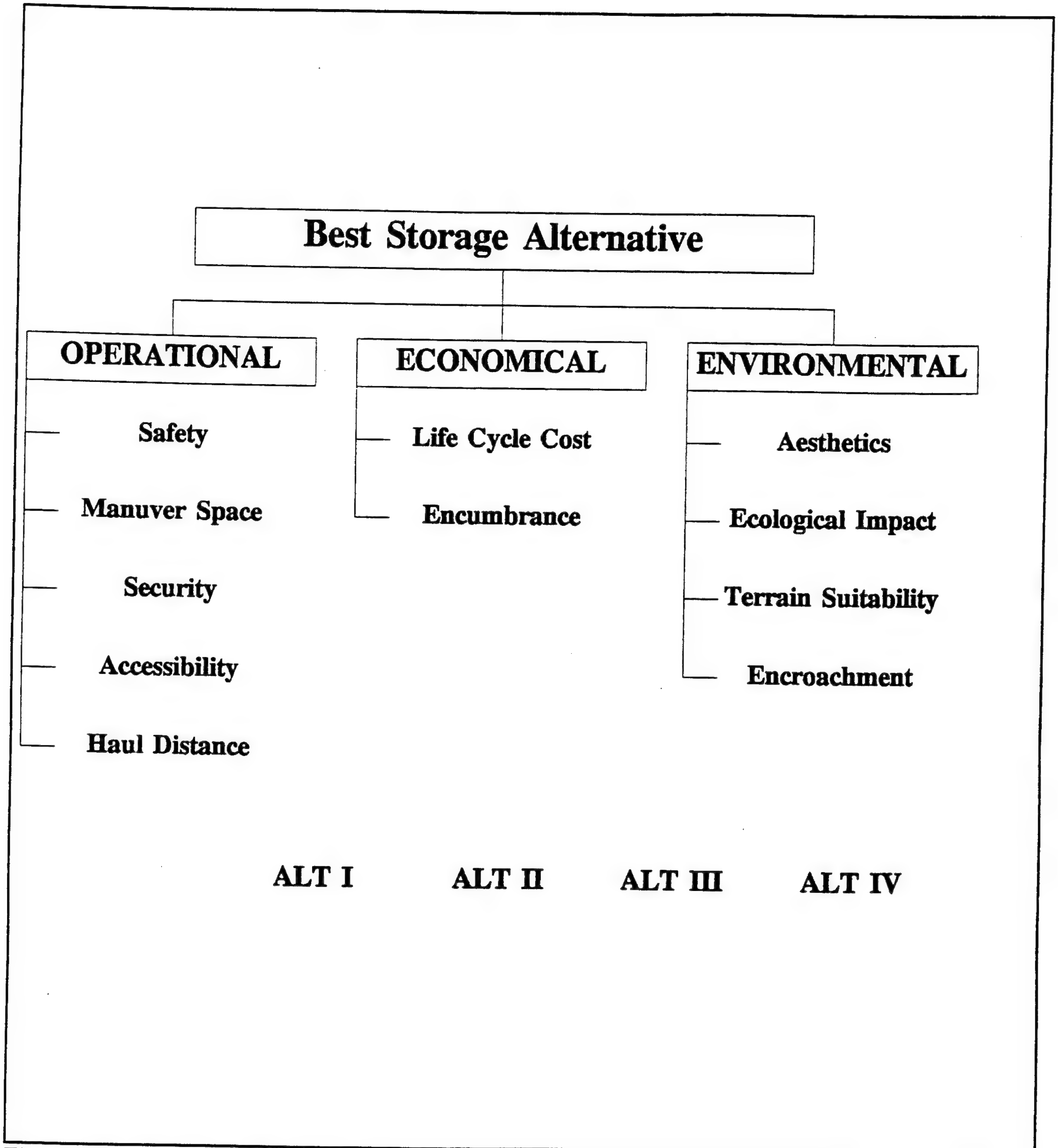
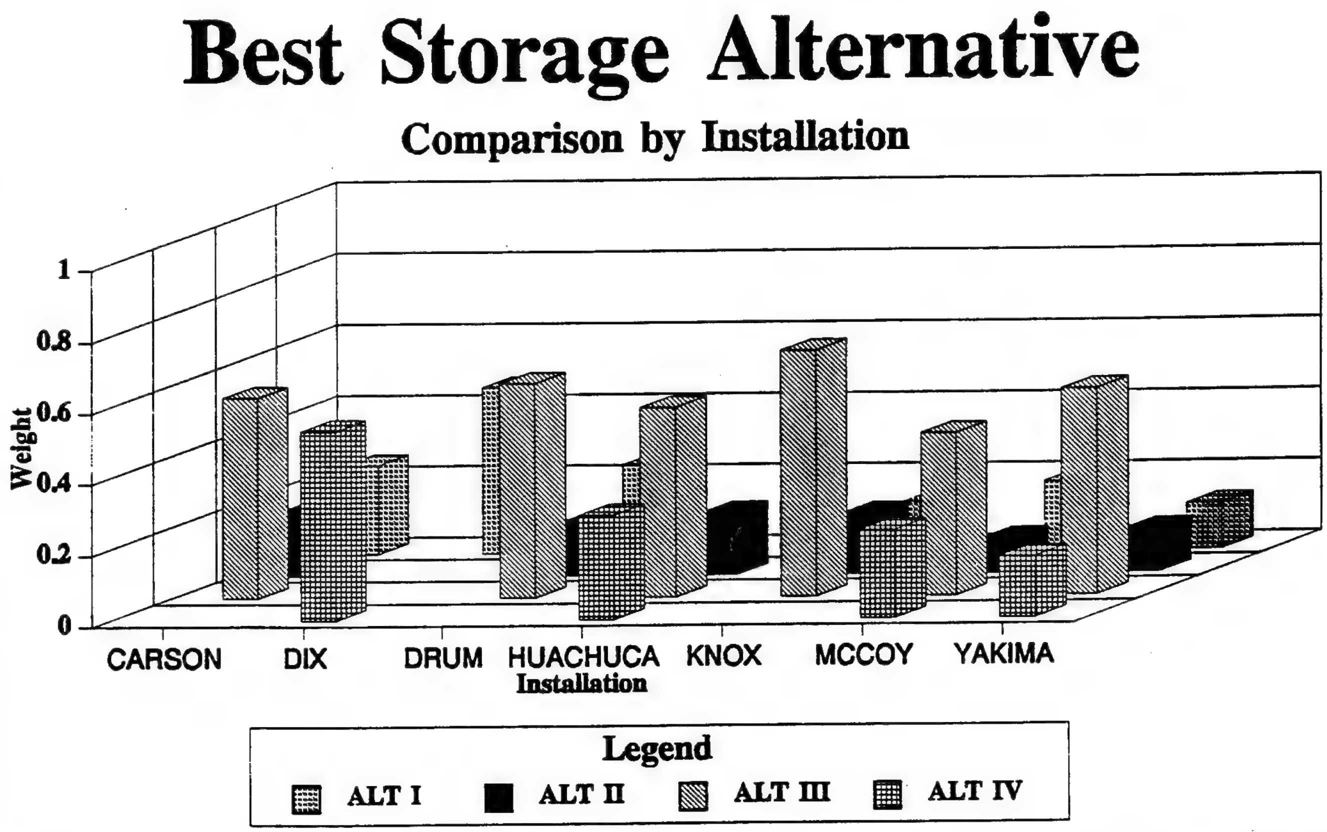
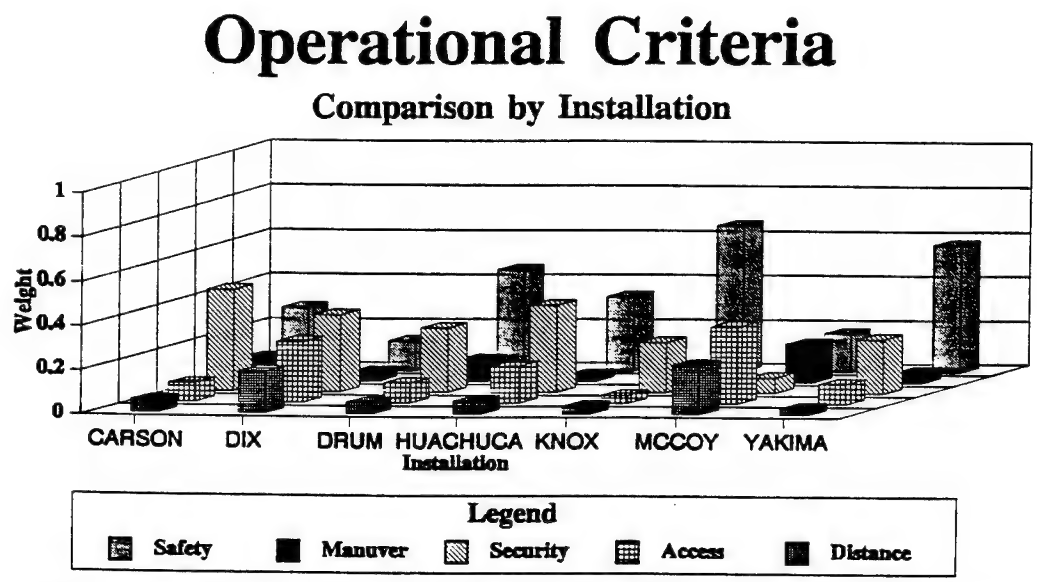


Figure C-8 Standard AHP Model



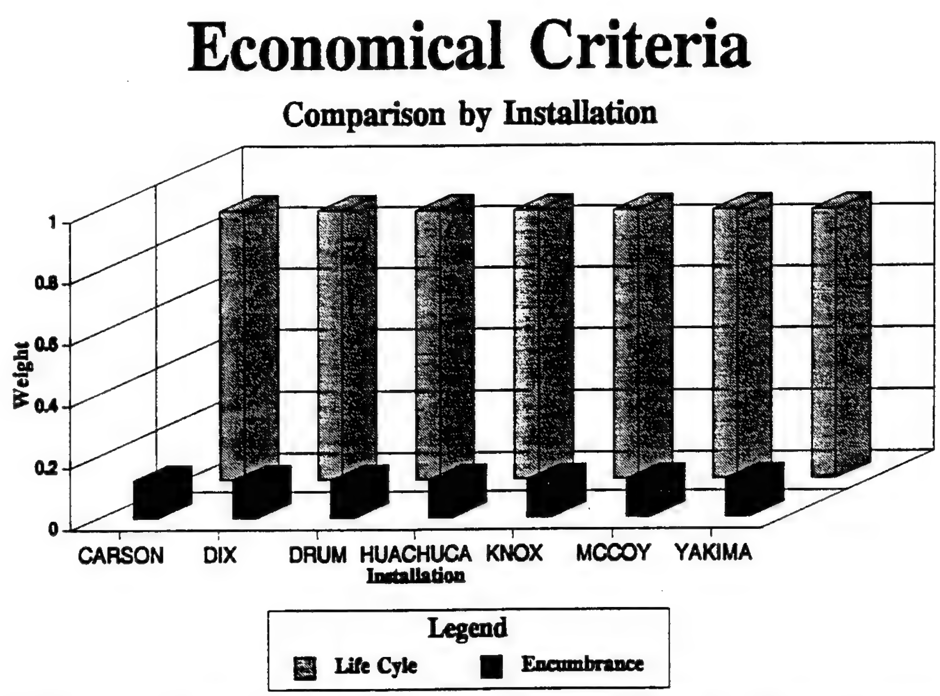
ALT I	0.249	0.467	0.247	NA	0.139	0.195	0.127
ALT II	0.186	NA	0.15	0.174	0.17	0.1	0.121
ALT III	0.565	NA	0.603	0.533	0.691	0.457	0.58
ALT IV	NA	0.533	NA	0.293	NA	0.248	0.173

Figure C-9 Best Overall AHP Alternatives by Installation



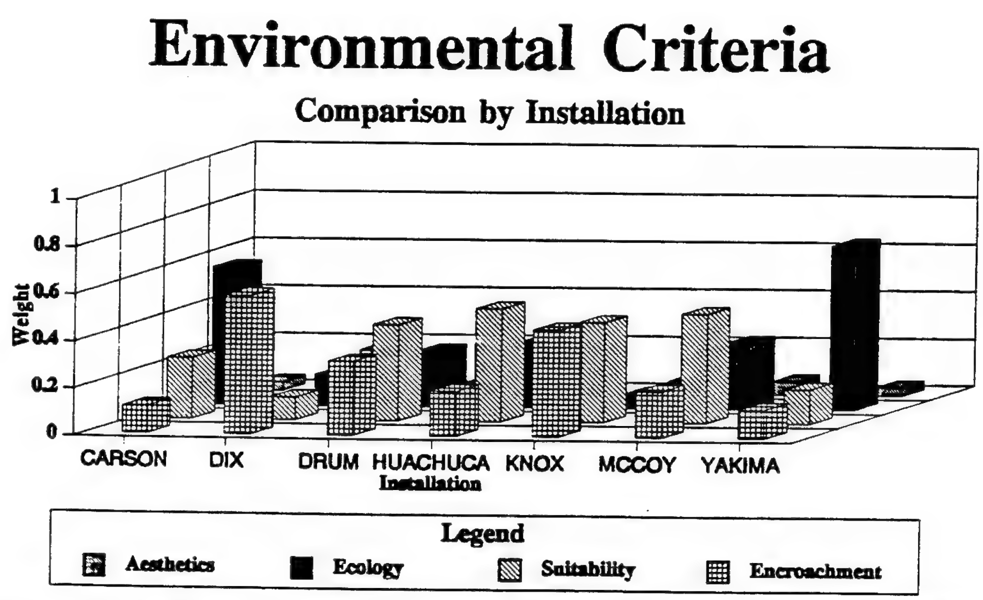
Safety	0.284	0.136	0.458	0.338	0.659	0.177	0.577
Manuver	0.108	0.044	0.101	0.033	0.037	0.177	0.05
Security	0.461	0.352	0.294	0.398	0.23	0.07	0.248
Access	0.087	0.277	0.093	0.169	0.037	0.351	0.092
Distance	0.06	0.191	0.054	0.061	0.037	0.226	0.032

Figure C-10 Operational Criteria Weights by Installation



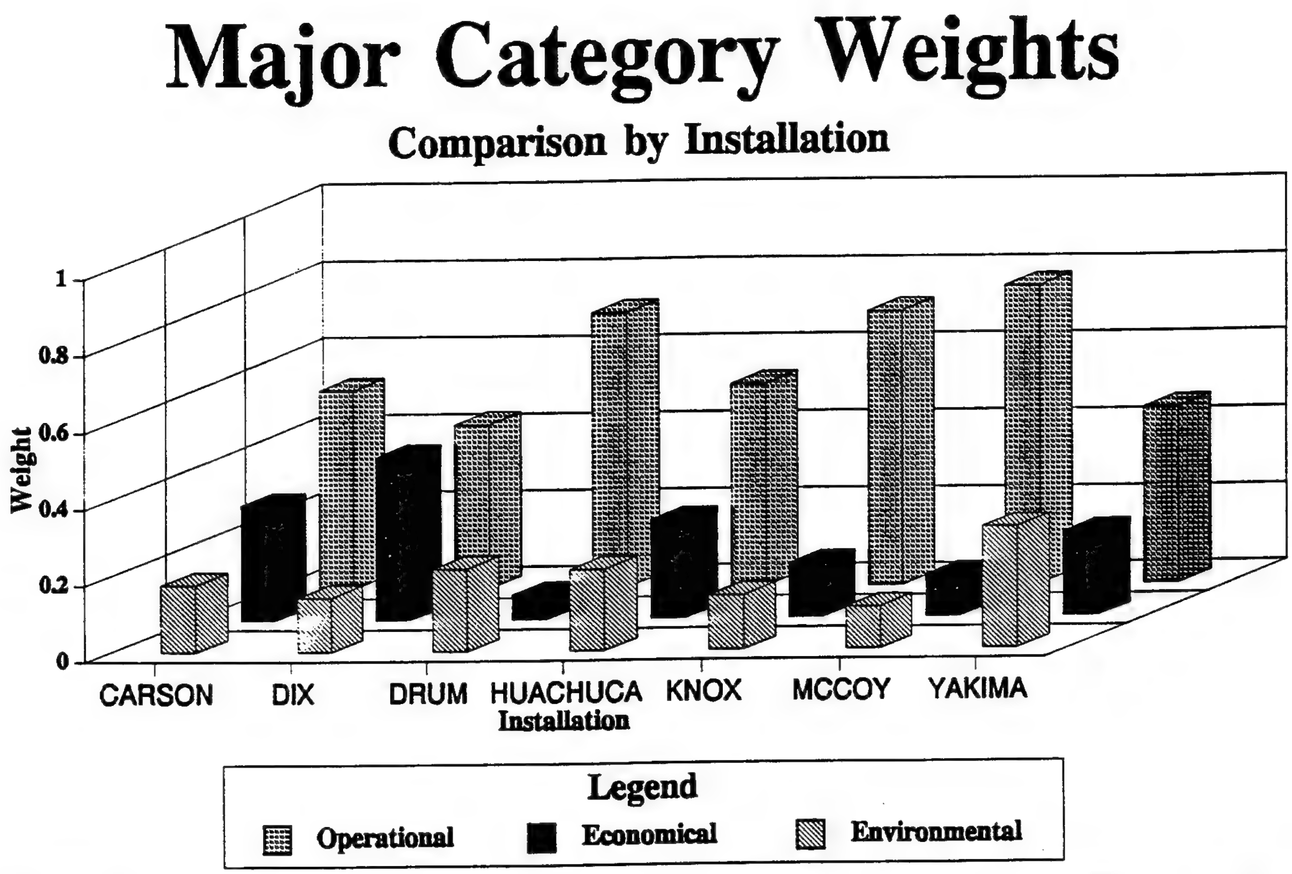
Life Cyle	0.875	0.875	0.875	0.875	0.875	0.875	0.875
Encumbra	0.125	0.125	0.125	0.125	0.125	0.125	0.125

Figure C-11 Economical Criteria Weights by Installation



Aesthetics	0.037	0.178	0.037	0.05	0.057	0.057	0.035
Ecology	0.584	0.135	0.239	0.28	0.061	0.283	0.696
Suitability	0.261	0.098	0.409	0.481	0.427	0.464	0.148
Encroach	0.117	0.589	0.315	0.19	0.455	0.197	0.122

Figure C-12 Environmental Criteria Weights by Installation



Operationa	0.519	0.429	0.715	0.527	0.714	0.778	0.46
Economic	0.304	0.429	0.067	0.26	0.143	0.111	0.221
Environme	0.177	0.143	0.218	0.214	0.143	0.111	0.319

Figure C-13 Major Category Weights by Installation

ANALYTIC HIERARCHY PROCESS QUESTIONNAIRE

PURPOSE: To elicit installation experts' judgements on the importance of each element in an analytic hierarchy process model for determining the optimum ammunition storage type for Fort ____________________. Your judgements will enable the capturing of the importance of intangible or non-quantifiable qualities of an alternative such as Underground Storage into the selection process of an optimum ammunition storage facility for your installation. A pairwise comparison technique will aid you in performing these judgements.

DESCRIPTION: The Analytic Hierarchy Process structure for determining the optimum ammunition storage at Fort ____________________ is shown below.

Optimum Ammunition Storage

OPERATIONAL	ECONOMICAL	ENVIRONMENTAL
Safety	**Utilities**	**Aesthetics**
Maneuver Space	**Construction**	**Ecological Impact**
Security	**Maintenance**	**Terrain Suitability**
Accessibility	**Encumbrance**	**Encroachment**
Haul Distance		

DEFINITION of TERMs:

Operational:	Major category of non-quantifiable factors involved or are impacted by the day to day activities of operating an ammunition storage point in support of training.
Economical:	Major category of cost elements for developing, constructing and sustaining the ammunition supply point operations.
Environmental	Major category of non-quantifiable factors impacting the quality of life of the installation, its surrounding fauna and flora.
Safety:	A characteristic of a storage site that describes the degree its physical features and storage facility layout contribute to reducing the probability of catastrophic damage to property, stocks and personnel.

Maneuver Space	A characteristic of a storage site that describes the lack of limitations or restrictions the site imposes on maneuvering units and weapon systems.
Security:	A characteristic of a storage site that describes the degree its physical features and storage facility layout aid the safeguarding of all ammunition stocks.
Accessibility:	A characteristic of a storage site that defines the ease of access to the site from major road networks for commercial trucks delivering or picking up ammunition cargo.
Haul Distance:	A characteristic of a storage site that describes the average over-the-road distance to training sites where the ammunition is consumed.
Utilities:	All costs associated with the consumption of energy during the operation of the site.
Construction:	All costs associated with the building of an ammunition storage site.
Maintenance:	All costs associated with the supply point operations, barrier and grounds maintenance of a ammunition storage site.
Encumbrance:	A cost factor equal to the real estate cost for the total acreage that is contained within the Quantity Distance (QD) limits of a storage site.
Aesthetics:	A characteristic of a storage site that describes its beauty and appeal to the senses of observers.
Ecological Impact:	A characteristic of a storage site that describes its positive effect on the surrounding terrain, its fauna and flora.
Terrain Suitability	A characteristic of a storage site that describes the availability of terrain suitable for horizontal tunneling construction techniques and the amount of rock overburden.
Encroachment:	A characteristic of a storage site that describes its vulnerability to the (present and future) spread of human habitation within its QD limits.

These elements are arranged in a series of tables to assist you in accomplishing the pairwise comparisons.

PROCEDURES: Indicate with an "X" in the appropriate column, the judgement which indicates the dominance (degree of importance) of the element in Column I over the corresponding one in its row in Column II with regard to the property in question. If in fact the element in Column II dominates, then mark a position to the right of the **equality** value.

Question: The element in Column I is of what importance to Optimum Ammunition Storage as compared to the element in Column II?

EXAMPLE

Optimum Ammunition Storage

Col I	Absolute	Very Strong	Strong	Moderate	Equal	Moderate	Strong	Very Strong	Absolute	**Col II**
Operation-al	**X (*A*)**									Economi-cal
Operation-al										Environ-mental
Economi-cal						**X(*B*)**				Environ-mental

Example (*A*) reads: " Operational factors are of **absolute importance for optimum ammunition storage** as compared to Economical factors."
Example (*B*) reads: " Environmental factors are of **moderate importance for optimum ammunition storage** as compared to Economical factors."
Please insert your "X" into this table.

Optimum Ammunition Storage

Col I	Absolute	Very Strong	Strong	Moderate	Equal	Moderate	Strong	Very Strong	Absolute	**Col II**
Operation-al										Economi-cal
Operation-al										Environ-mental
Economi-cal										Environ-mental

PROCEDURES: Indicate with an "X" in the appropriate column, the judgement which indicates the dominance (degree of importance) of the element in Column I over the corresponding one in its row in Column II with regard to the property in question. If in fact the element in Column II dominates, then mark a position to the right of the **equality** value.

Question: The element in Column I is of what importance to the Category of Operational Factors as compared to the element in Column II?

Category of Operational Factors

Col I	Absolute	Very Strong	Strong	Moderate	Equal	Moderate	Strong	Very Strong	Absolute	**Col II**
Safety										Maneuver Space
Safety										Security
Safety										Accessibi-lity
Safety										Haul Distance
Maneuver Space										Security
Maneuver Space										Accessibi-lity
Maneuver Space										Haul Distance
Security										Accessibi-lity
Security										Haul Distance
Accessibi-lity										Haul Distance

PROCEDURES: Indicate with an "X" in the appropriate column, the judgement which indicates the dominance (degree of importance) of the element in Column I over the corresponding one in its row in Column II with regard to the property in question. If in fact the element in Column II dominates, then mark a position to the right of the **equality** value.

Question: The element in Column I is of what importance to the Category of Economical Factors as compared to the element in Column II?

Category of Economical Factors

Col I	Absolute	Very Strong	Strong	Moderate	Equal	Moderate	Strong	Very Strong	Absolute	**Col II**
Utilities										Construc-tion
Utilities										Mainte-nance
Utilities										Encumb-rance
Construc-tion										Mainte-nance
Construc-tion										Encumb-rance
Mainte-nance										Encumb-rance

PROCEDURES: Indicate with an "X" in the appropriate column, the judgement which indicates the dominance (degree of importance) of the element in Column I over the corresponding one in its row in Column II with regard to the property in question. If in fact the element in Column II dominates, then mark a position to the right of the **equality** value.

Question: The element in Column I is of what importance to the Category of Environmental Factors as compared to the element in Column II?

Category of Environmental Factors

Col I	Absolute	Very Strong	Strong	Moderate	Equal	Moderate	Strong	Very Strong	Absolute	**Col II**
Aesthe-tics										Ecologica l Impact
Aesthe-tics										Terrain Suitabilit y
Aesthe-tics										Encroach -ment
Ecologica l Impact										Terrain Suitabilit y
Ecologica l Impact										Encroach -ment
Terrain Suitabilit y										Encroach -ment

ANNEX D

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13. ABSTRACT *(Maximum 200 words)*

This study examines the economics and qualitative decision factors which would support a decision to replace existing aboveground ammunition storage facilities with underground ammunition storage facilities at eight U.S. Army installations in the United States. The MTA Team of researchers visited the installations and noted the condition and operation status of the ammunition facilities. The Team evaluated shortfalls in storage capacity, safety, security, or other management functions at the existing storage site through frank discussions with ammunition managers, Quality Assurance Specialists Ammunition Surveillance (QASAS), and representatives of the Director of Logistics and the Director of Public Works.

The study presents two quantitative decision criteria: life cycle costing and real estate encumbrance; and one combined qualitative/quantitative criteria: the AHP to assist in the selection of a particular alternative. MTA believes that a combination of the traditional engineering economy methods (which emphasize the time value of money and real estate impacts) along with the AHP (which is an excellent method to weigh those nonquantifiable factors of safety, security, environmental concerns) is the preferred method to make ammunition storage expansion decisions.

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